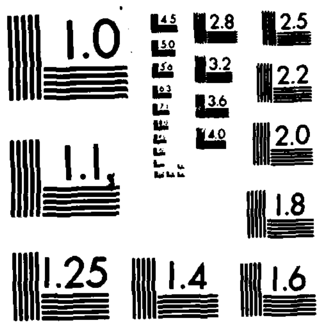
AD-A129 206 GRAPHITE COMPOSITE LANDING GEAR COMPONENTS VOLUME II 1/3
TECHNICAL APPENDICES(U) HERCULES INC MAGNA UT BACCHUS
WORKS L C JENSEN ET AL. JUN 77 AFFDL-TR-77-20-VOL-2
UNCLASSIFIED F33615-72-C-1725 F/G 1/3 NL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AFFDL-TR-77-20
VOLUME II

FINAL REPORT GRAPHITE COMPOSITE LANDING GEAR COMPONENTS
APPENDICES
VOLUME II

HERCULES INCORPORATED, SYSTEMS GROUP
BACCHUS WORKS, MAGNA, UTAH

JUNE 1977

TECHNICAL REPORT AFFDL-TR-77-20, VOLUME II

FINAL REPORT FOR PERIOD FEBRUARY 1973 - FEBRUARY 1977

APPROVED FOR PUBLIC RELEASE;
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WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This technical report has been reviewed and is approved for publication.

George J. Sperry
Acting Technical Manager
Special Projects Group
Vehicle Equipment Division

Dr. Howell K. Brewer, Chief
Mechanical Branch
Vehicle Equipment Division
Air Force Flight Dynamics Laboratory

FOR THE COMMANDER

Ambrose B. Nutt, Director
Vehicle Equipment Division
Air Force Flight Dynamics Laboratory

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AIR FORCE/56780/25 October 1977 — 250

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7. AUTHOR(s) L. C. JENSEN, H. L. PRITT		8. CONTRACT OR GRANT NUMBER(s) F33615-72-C-1725
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18. SUPPLEMENTARY NOTES

THIS FINAL REPORT IS CONTAINED IN TWO VOLUMES
VOLUME I TECHNICAL DISCUSSION
VOLUME II APPENDICES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

LANDING GEAR	A37B AIRCRAFT	LANDING GEAR GEOMETRY
OUTER CYLINDER	TORQUE ARM ATTACHMENT	LANDING GEAR DESIGN LOADS
TRUNNION	SIDE BRACE ATTACHMENT	LANDING GEAR FABRICATION
GRAPHITE EPOXY	COMPOSITE MATERIAL	LANDING GEAR LAB TEST

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

(See Reverse Side)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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The objectives of this effort were to determine the feasibility of, and the weight and cost savings from the manufacture of a direct replacement landing gear for current Air Force aircraft which is composed of component hardware that is fabricated from graphite epoxy material to the maximum extent possible. Prior to the start of this effort, direct replacement torque arm and side brace components for the A37B aircraft landing gear had been qualified for flight use which were fabricated from epoxy materials to the maximum extent possible. Both of these components were lighter than the existing metallic components. It was projected that the fabrication cost of the side-brace in production quantities would be less than the existing metallic component. Under a separate In-House Work Unit, the graphite epoxy side brace successfully passed extensive laboratory environmental and in-service flight testing. The major task under this effort was the design, fabrication and qualification of an A37B aircraft outer cylinder/trunnion fabricated from graphite epoxy material to the maximum extent possible. After three trunnion design and fabrication iterations, the effort was terminated. Based on current graphite epoxy design and fabrication limitations, it was determined that a successful direct replacement trunnion could not now be fabricated due to existing landing gear compartment and other space limitations. The effort demonstrated that the complex trunnion could be designed and fabricated using an optimum amount of graphite epoxy material with a weight saving of 21 percent in comparison to existing metallic hardware. Potential weight and cost savings exist for the fabrication of new aircraft landing gear trunnions from graphite epoxy material, where the trunnion design is not limited by existing space limitations. Future graphite epoxy material and/or manufacturing improvements could make the fabrication direct replacement trunnion components feasible and profitable.

FOREWORD

This report was prepared by Hercules Incorporated, Bacchus Works, Magna, Utah under United States Air Force Contract F33615-72-1725, Project 1369, Task 03, Graphite Composite Landing Gear Components. The program was administered by the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, under the direction of Gerald C. Shumaker (AFFDL/FEM).

This is Volume II, Appendices, of the final report, two volumes, covering the work performed from February 28, 1973 to February 1977. Volume I of the report contains the technical discussion. Hercules personnel directly participating on the program were:

Program Manager	L. C. Jensen
Program Engineer	H. L. Pritt
Fabrication Engineer	J. Witzel
Design Supervisor	J. N. Burns
Design Engineer	E. R. Torres
Design Engineer	R. E. Thompson

The report was submitted by the authors for publication as a Technical Report in June 1977.

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DESIGN ANALYSIS
OF
THE OUTER CYLINDER/TRUNNION AND ATTACHMENTS

APPENDIX A

PART I

DESIGN ANALYSIS
OF
THE SIDEBRACE ATTACHMENT

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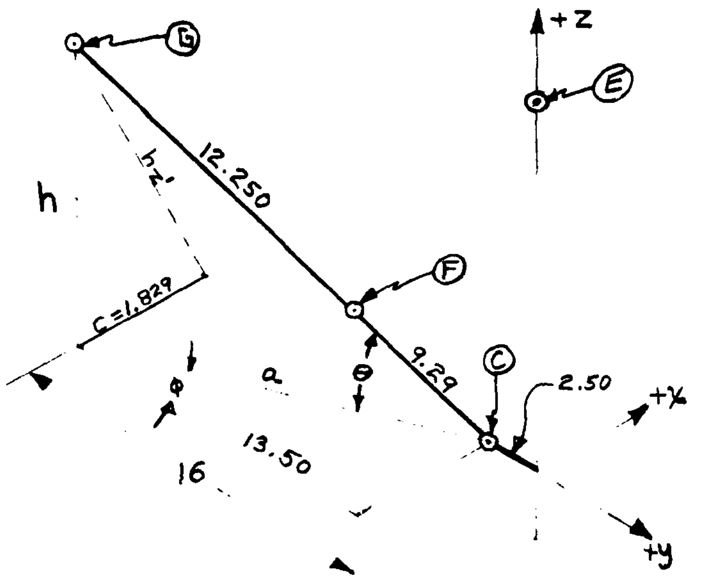
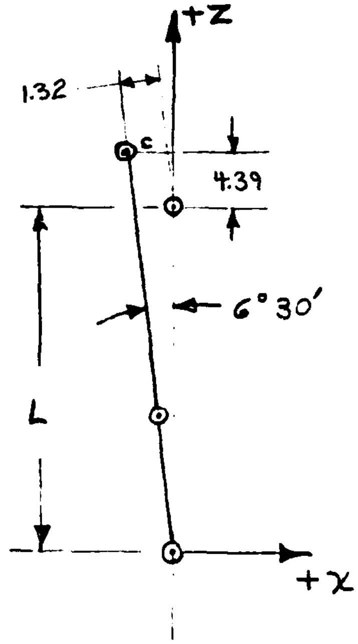
SKETCH NO. I.2

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE A-37B LANDING GEAR

ORIGINAL SIDE BRACE GEOMETRY





$$C = \frac{1.32}{\cos 6^\circ 30'} + \tan 6^\circ 30' (4.39) = \frac{1.32}{.9936} + .1139\,(4.30) = 1.829$$

$$\tan \phi = \frac{1.829}{13.50} = .1355 \;,\; \phi = 7^\circ 43'$$

$$a = \frac{13.50}{\cos \phi} = \frac{13.50}{.9909} = 13.623$$

$$\cos \theta = \frac{a}{21.54} = .632 \;,\; \theta = 51^\circ 28'$$

$$h = \sin \theta\,(21.54) = .7823\,(21.54) = 16.851 \text{ IN}$$

$$L = h - 4.39 = 12.461 \text{ IN}$$

$$h_z' = h + \tan 6^\circ 30' (1.829) = 17.059$$

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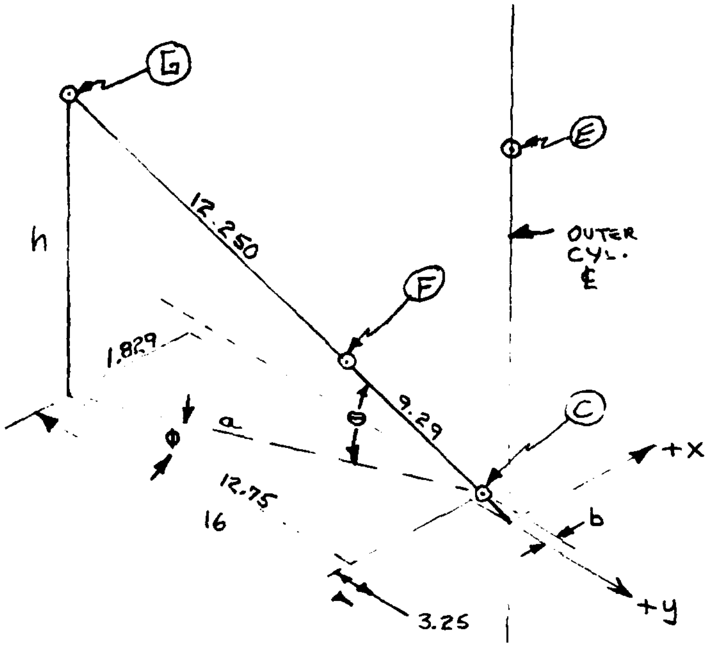
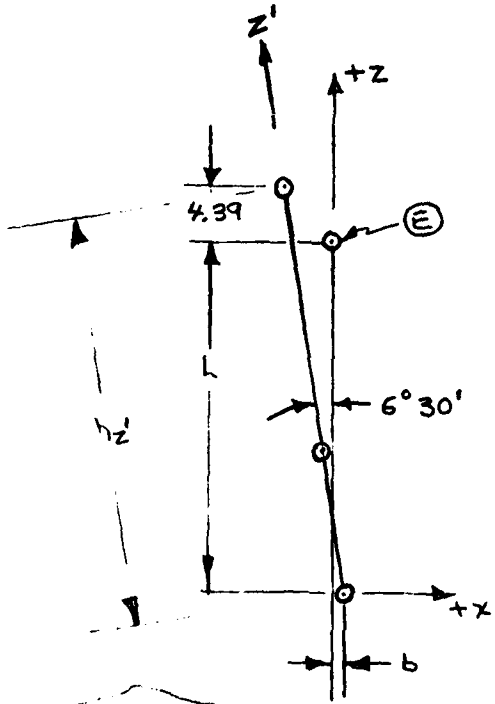
SKETCH NO. I. 3

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE A-37 B LANDING GEAR

SIDE BRACE
GEOMETRY, GRAPHITE DESIGN





$g = 16.0 - 3.25 = 12.75"$

$h_{z'} = [(21.54)^2 - g^2]^{1/2} = 17.361"$

$h = h_{z'} \cos 6°30' = 17.361\,(.9936) = 17.250$

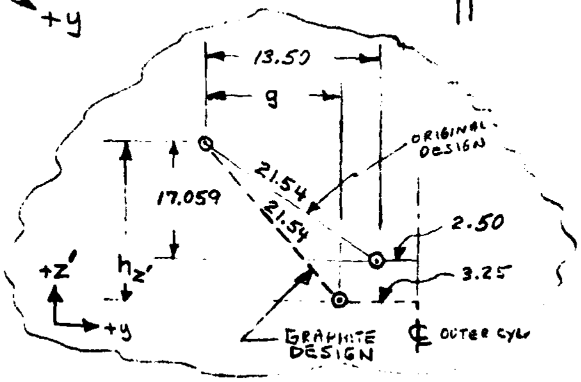
$L = h - 4.39 = 12.860$

$\sin \theta = h/21.54 = .8008 \quad , \theta = 53°\,12'$

$a = 21.54 \cos \theta = 12.903$

$\cos \phi = 12.75/a = .9881 \quad , \phi = 8°\,51'$

$b = a \sin \phi - 1.829 = a(.1539) - 1.829 = 0.157$ IN.



REFERENCES

① HERCULES INTERIM REPORT, PHASE I GRAPHITE COMPOSITE GEAR COMPONENTS, CONTRACT # F33615-71-C-1508, DOCUMENT # H4N-12-1-3, 3 MAY 1971

② BENDIX THIRD INTERIM REPORT, CONTRACT # F33615-69-C-1568, DATED 14 DEC. 1970

③ HERCULES DWG # 3008S00433, ORIGINAL DESIGN = 2.5", BENDIX DESIGN 3.12 (②)

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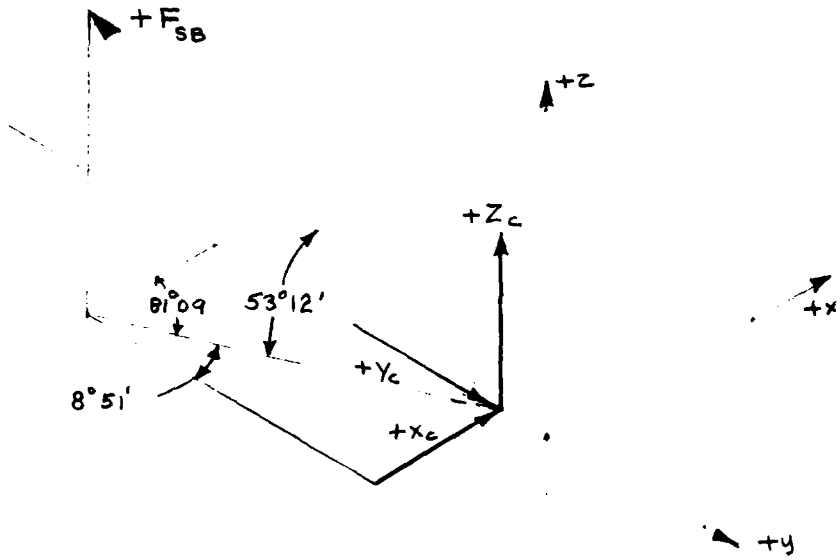
SKETCH NO. I.4

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE A-37B LANDING GEAR

SIDE BRACE

ULT. LOADS



$$F_{SB} = (\cos 81°09')(\cos 53°12')(-X_c) + (\cos 8°51')(\cos 53°12')(-Y_c) + \cos 36°48'(Z_c)$$

$$= -.092\,X_c - .592\,Y_c + .8007\,Z_c$$

LOAD CONDITION	Z_c	Y_c	X_c	F_{SB}	
1 A	-9300	7500	1100	- 9838	
1 B	-4100	3300	500	- 5282	
1 C	-7600	6200	900	- 9838	
2 A	-8900	7230	1000	-11500	
2 C	-5600	4600	600	- 7262	
3 A	9000	-7300	-1000	(+11,619)	CRITICAL TENSILE LOAD
3 B	-22,600	18300	2600	-29,166	
4 A	-6,300	5100	700	- 8,128	
5 A	-6,300	5100	700	- 8,128	
6 A	-22,700	18,400	2600	(-29,306)	CRITICAL COMPRESSIVE LOAD

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SKETCH NO. I.5

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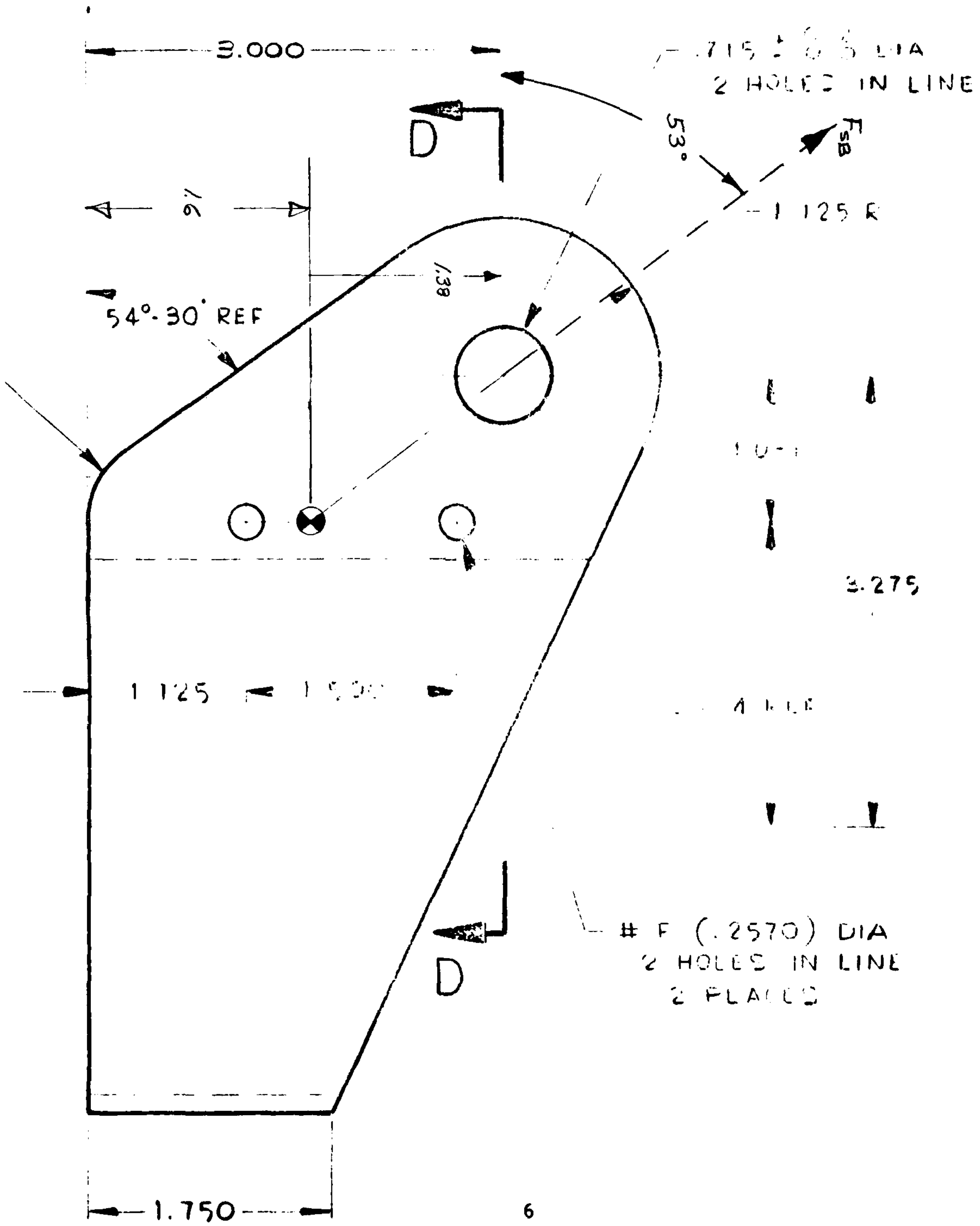

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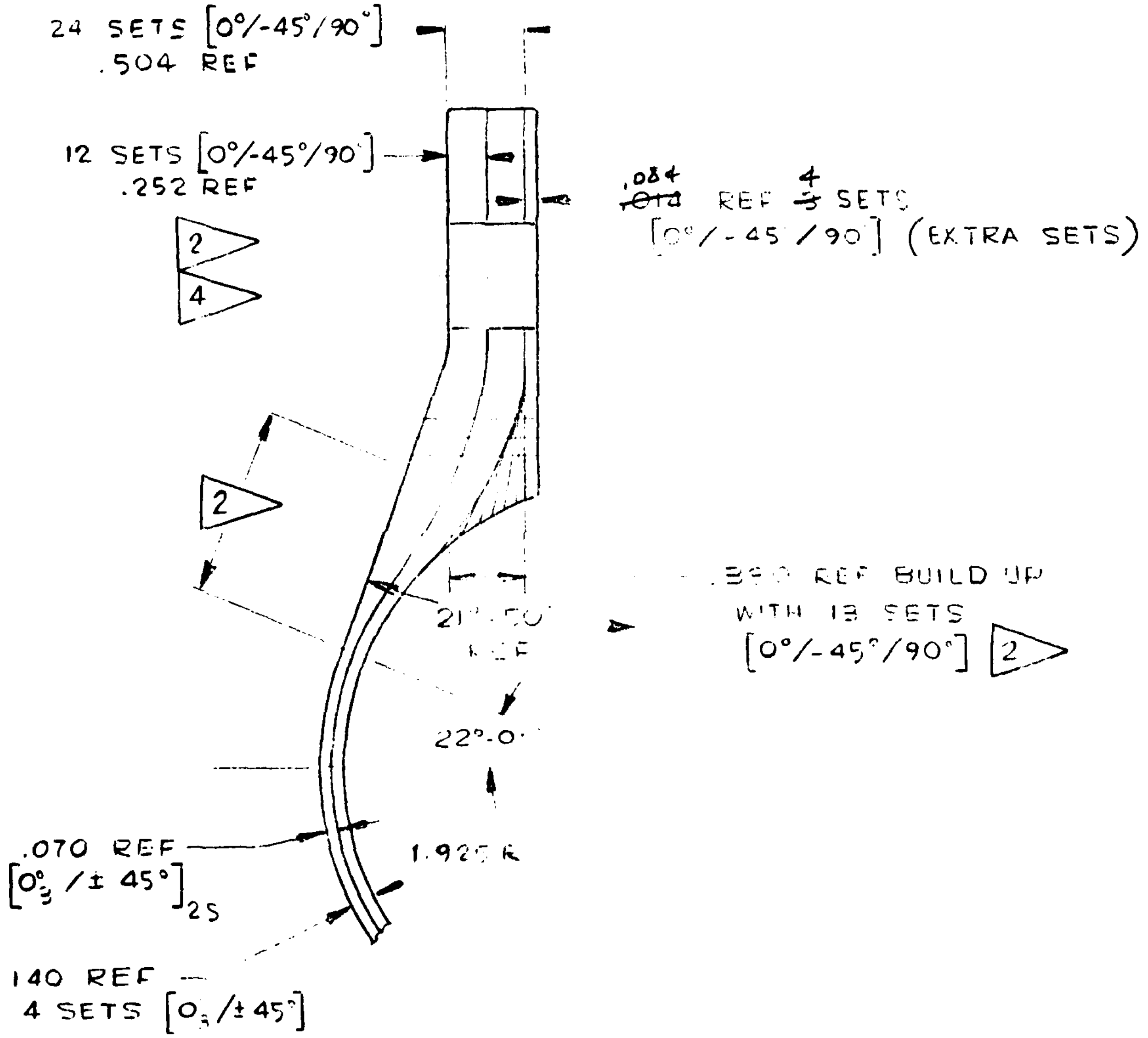

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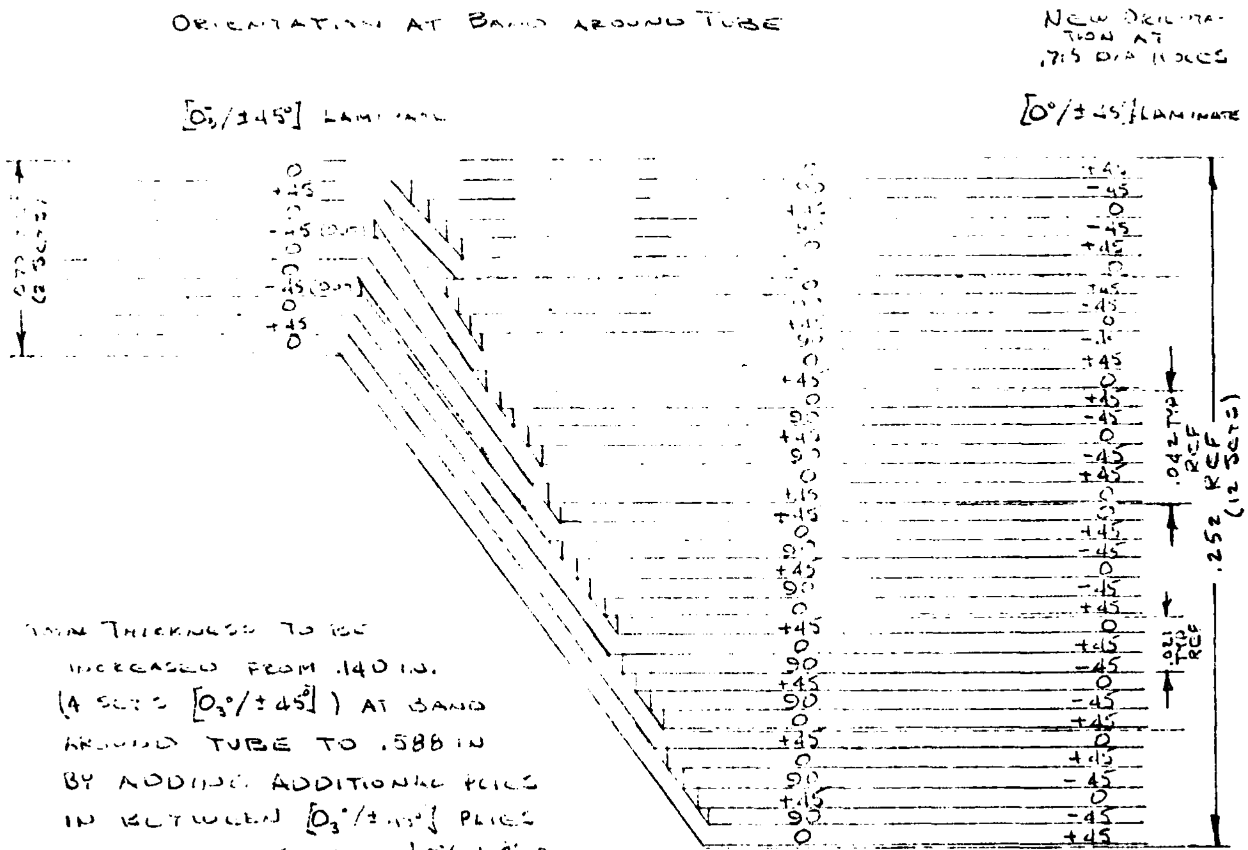
BLDG. ______ TITLE ______



SKIN THICKNESS TO BE INCREASED FROM .140 IN. (4 SETS [0_3°/±45°]) AT BAND AROUND TUBE TO .588 IN BY ADDING ADDITIONAL PLIES IN BETWEEN [0_3°/±45°] PLIES PLUS 4 MORE SETS OF [0°/±45°] PLIES (NEW ORIENTATION). THE NEW ORIENTATION WAS SET UP WITH 0° PLY PARALLEL TO + OR − 45° WITH RESPECT TO THE CIRCUMFERENTIAL PLIES — FOR ANALYSIS PURPOSES.

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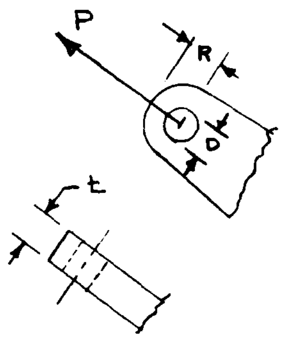
SKETCH NO. I.8

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR gmB

BLDG. ______ TITLE A-37B LANDING GEAR

SIDE BRACE LUG ANALYSIS } TENSILE LOAD



LAY-UP: $[0 \pm 45]_s$ WITH 0° PLY ‖ to P

$P = 70\% \times F_{SB} = .70 \times 11{,}619 = 8{,}133^{\#}$

R = 1.125 IN

D = .717 IN

e = 90% × R = 1.013 IN

t = 0.560 IN

S = R − .5D = 1.25 − .359 = .891 IN

S/D = 1.24

e/D = 1.41

$A_s = 2et = 1.135$

$A_{br} = Dt = .402\ IN^2$

$A_t = (2R - D)t = .857\ IN^2$

ALLOWABLE BEARING STRESS

USING CURVE ON P. I.9 FOR e/D = 1.41

F_{BR} ① = 97,000 PSI

$F_{BR_{ALLOWABLE}}$ = 50% ② × F_{BR} : 48,500 PSI

ALLOWABLE TENSILE STRESS AT 1-1

$$F_{tu} = \frac{F_{BR_{ALL}}}{2(S/D - 0.5)} = \frac{48{,}500}{2(1.24 - .5)} = 32{,}800 \text{ PSI}$$

ALLOWABLE SHEAR TEAR OUT STRESS

$$F_{su} = \frac{F_{BR_{ALL}}}{2(e/D - 0.5)} = \frac{48{,}500}{2(1.41 - .5)} = 26{,}600 \text{ PSI}$$

① CURVE ON PAGE I.10 INDICATES F_{BR} = 75,000 PSI FOR D/t = 1.28

② FACTOR TO ACCOUNT FOR FATIGUE AND UNCERTAINTIES IN F_{BR} VALUES

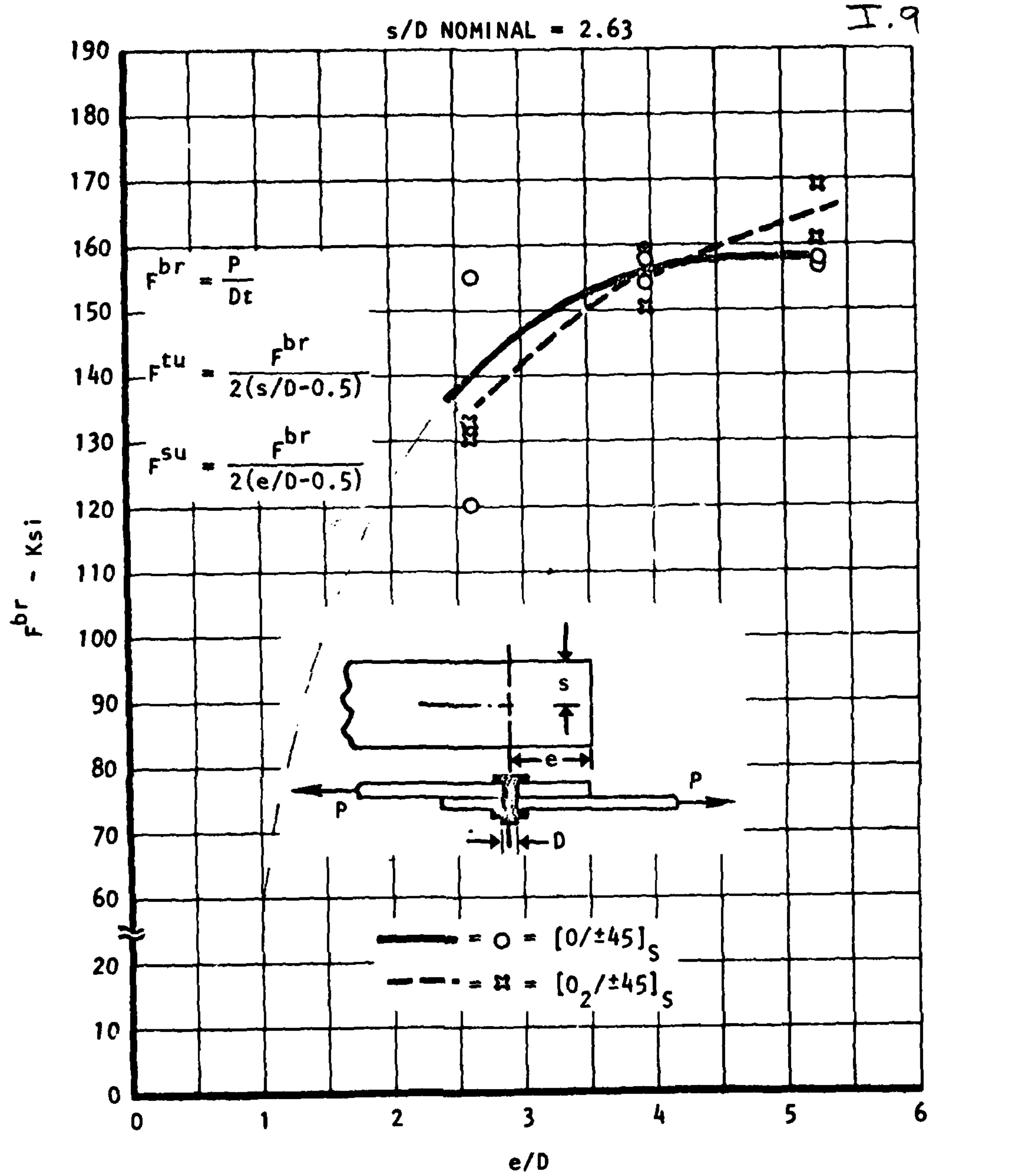


Figure 140. Graphite/Epoxy to Steel Mechanical Joint Single Lap Bearing Strength Versus e/D at Room Temperature (Type AS/3002, Batch) Protruding Head Fastener

REF: ADVANCED COMPOSITE DATA FOR AIRCRAFT STRUCTURAL DESIGN, VOL. IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY, NORTH AMERICAN ROCKWELL/L.A. DIVISION, REPORT # AFML-TR-70-58, SEPT. 1972

Graphite/epoxy data on equivalent bearing strength F^{br} versus D/t, for various laminate layup orientations of Narmco 5206, Type II, are presented in Figures 6.2.2.23 and 6.2.2.24, which were obtained from Reference 6.8. The design curves shown represent the lower bound data and are valid for the parameter range designated. Countersunk fastener joint data are presented in paragraph 6.2.2.1.2.

6.2.2.1.1.4 Elevated-Temperature Effects - The strength reduction in boron/epoxy test data for temperatures up to 375°F are shown in Figure 6.2.2.25 from References 6.2 and 6.25. The shearout, net-tension, and bearing temperature correction curves shown should be considered applicable only for the laminate orientations designated.

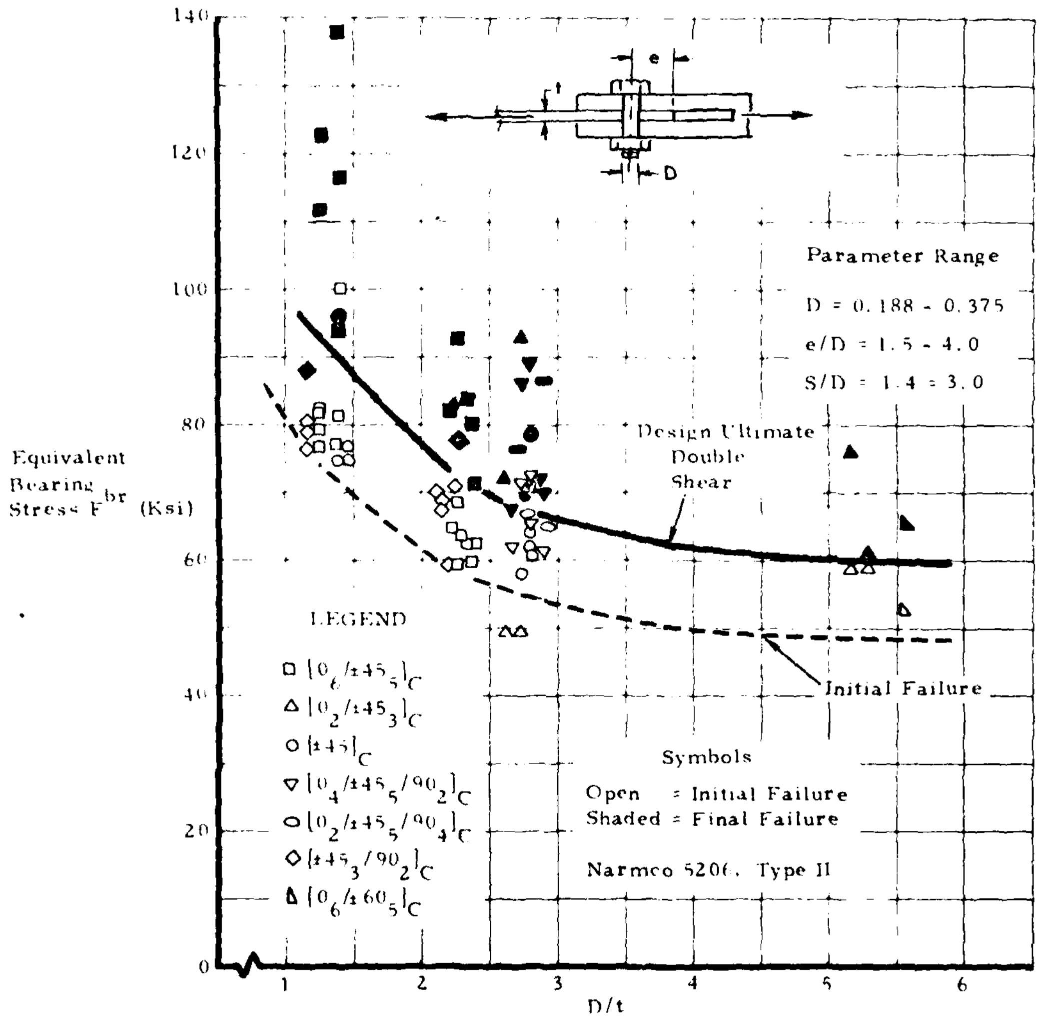


FIGURE 6.2.2.23 GRAPHITE/EPOXY MECHANICAL JOINT STRENGTH - DOUBLE SHEAR

TAKEN FROM AIR FORCE DESIGN GUIDE

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BLDG. ______ TITLE A-37B LANDING GEAR

SIDE BRACE
LUG ANALYSIS, CON'T

STRESSES

$$f_{BR} = \frac{P}{A_{br}} = \frac{8,133}{.402} = \underline{\underline{20,200 \text{ PSI}}}$$

$$m.s. = \frac{48,500}{20,200} - 1 = \underline{\underline{+1.40}}$$

$$f_t = \frac{P}{A_t} = \frac{8,133}{.857} = \underline{\underline{9,500 \text{ PSI}}}$$

$$m.s. = \frac{32,800}{9,500} - 1 = \underline{\underline{+2.46}}$$

$$f_s = \frac{P}{A_s} = \frac{8,133}{1.135} = \underline{\underline{7,170 \text{ PSI}}}$$

$$m.s. = \frac{26,600}{7,170} - 1 = \underline{\underline{+2.72}}$$

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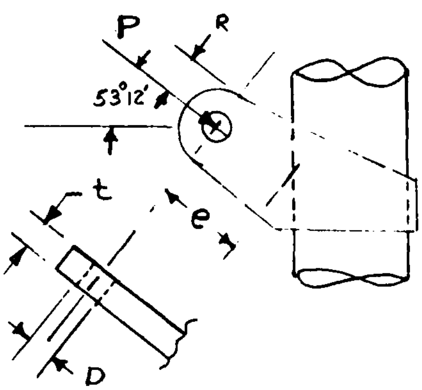
SIDE BRACE LUG ANALYSIS } COMPRESSIVE LOAD



LAY UP: $[0 \pm 45]_s$ WITH 0° PLIES ‖ to P

$P = 70\% (-F_{SB}) = .7 (29,306) = 20,514$

$D = .717$

$e = 1.8$

$t = 0.56$

$R = 1.125$

$S = R - .5D = .891$

$S/D = 1.24$

$e/D = 2.51$

$A_{br} = Dt = .402$

$A_t = (2R-D)t = .857$

$A_s = 2et = 2.02$

ALLOWABLE BEARING STRESS

USING CURVE ON P. I.9 FOR $e/D = 2.51$

$F_{BR} = 138,000$ PSI

$F_{BR_{ALL}} = 50\% \times 138,000 = 69,000$ PSI

ALLOWABLE TENSILE STRESS

$$F_{tu} = \frac{F_{BR_{ALL}}}{2(S/D - 0.5)} = \frac{69,000}{1.48} = 46,603 \text{ PSI}$$

ALLOWABLE SHEAR TEAR OUT STRESS

$$F_{su} = \frac{F_{BR}}{2(e/D - 0.5)} = \frac{69,000}{4.02} = 17,200 \text{ PSI}$$

SIDE BRACE
LUG ANALYSIS, CON'T

STRESSES

$$f_{BR} = \frac{P}{A_{br}} = \frac{20{,}514}{.402} = \underline{\underline{51{,}200 \text{ PSI}}}$$

$$m.s. = \frac{67{,}000}{51{,}200} - 1 = \underline{\underline{+0.35}}$$

$$f_t = \frac{P}{A_t} = \frac{20{,}514}{.857} = \underline{\underline{23{,}900 \text{ PSI}}}$$

$$m.s. = \frac{46{,}600}{23{,}900} - 1 = \underline{\underline{+0.95}}$$

$$f_s = \frac{P}{A_s} = \frac{20{,}514}{2.02} = \underline{\underline{10{,}150 \text{ PSI}}}$$

$$m.s. = \frac{17{,}200}{10{,}150} - 1 = \underline{\underline{+0.70}}$$

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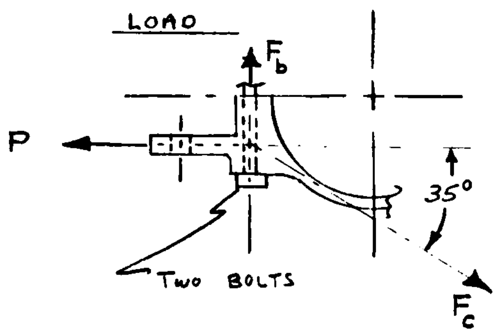
SKETCH NO. I.14

PLANT ____ PROJECT NO. ____ DATE 2-73 AUTHOR gnB

BLDG. ____ TITLE A-37B LANDING GEAR

SIDE BRACE ATTACHMENTS
BOLTS (TENSILE LOAD)



$$\max +P = 70\% \times F_{SR} = .7\,(11{,}619) = 8133\,\#$$

$$F_c = \frac{+P}{\cos 35^\circ} = \frac{8133}{.8192} = 9928\,\#$$

$$F_b = +P\tan 35^\circ = (8133)(.7002) = 5{,}695\,\#$$

BOLT & NUT TYPE

BOLT : NAS 1271-48 (SEE P. I.16 & I.17)
TENSILE LOAD, MAX = 5820 LBS

NUT : FNT 20-428 (SEE P. I.18)
TENSILE LOAD = 7270 LBS

MARGIN OF SAFETY ON 1/4-28 BOLT

$$m.s. = \frac{2 \times 5820}{5{,}695} - 1 = \underline{\underline{+1.04}}$$

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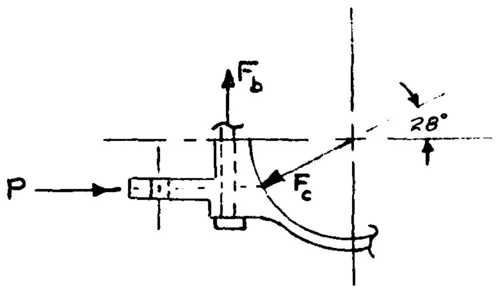
SKETCH NO. I.15

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR [illegible]

BLDG. ______ TITLE ______

SIDE BRACE ATTACHMENT
BOLTS (COMPRESSIVE LOAD)



$$\max P = 70\% \times F_{SB} = .7\,(29{,}303) = 20{,}514\ \#$$

$$F_c = P/\cos 28° = 20{,}514/.883 = 23{,}200\ \#$$

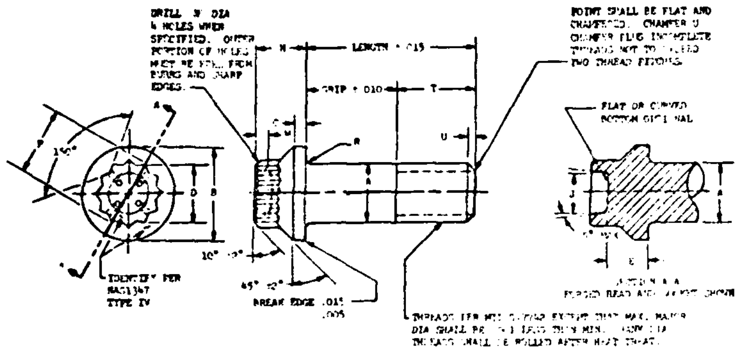
$$F_b = P \tan 28° = 20{,}514\,(.5317) = 10{,}900\ \#$$

MARGIN OF SAFETY FOR 1/4-28 BOLT

$$m.s. = \frac{2 \times 5820}{10{,}900} - 1 = \underline{\underline{+0.07}}$$

NATIONAL AEROSPACE STANDARD

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC. 610 SHOREHAM BUILDING WASHINGTON 5 D C



BASIC PART NUMBER	THREAD 3A	A (d)	B (d) ±.005	C ±.010	D (d)	E MIN	H ±.010	J	M ±.011	N	F REF	R	T REF	U REF	CONCENTRICITY DATA (d) X	Y	Z
NAS 1271	1/4 -28	.2495 .2490	.433	.060	.315 .306	.135	.300	.190	.062	.037	.370	.041 .031	.635	.05	[illegible]	[illegible]	[illegible]
NAS 1272	5/16-24	.3120 .3113	.576	.082	.377 .368	.162	.348	.215	.070	.055	.431	.041 .031	.572	.05	[illegible]	.005	.004
NAS 1273	3/8 -24	.3745 .3735	.644	.091	.439 .430	.197	.348	.260	.070	.055	.502	.057 .047	.619	[illegible]	.008	.006	.004
NAS 1274	7/16-20	.4370 .4360	.765	.099	.503 .494	.229	.435	.320	.070	.055	.576	.057 .047	.666	.06	[illegible]	[illegible]	.004
NAS 1275	1/2 -20	.4995 .4985	.823	.123	.565 .556	.254	.504	.380	.094	.055	.648	.057 .047	.741	.08	.010	[illegible]	.004
NAS 1276	9/16-18	.5615 .5605	.933	.133	.629 .610	.287	.557	[illegible]	.094	.055	.720	.057 .047	.826	.08	.011	[illegible]	.006
NAS 1277	5/8 -18	.6240 .6230	1.045	.150	[illegible]	.327	.619	.500	.094	.055	.794	.073 .063	.873	.09	[illegible]	[illegible]	.006
NAS 1278	3/4 -16	.7490 .7480	1.225	.179	.817 .808	.380	.711	.570	.094	.055	.939	.073 .063	.993	.09	.015	.012	.006
NAS 1279	7/8 -14	.8740 .8730	1.433	.198	.943 .934	.438	.868	.650	.125	.055	1.083	.073 .063	1.196	.10	.018	.014	.009
NAS 1280	1 -12	.9990 .9980	1.620	.222	1.076 1.065	.493	.923	.760	.125	.055	1.228	.073 .063	1.382	.10	.020	.016	.009

NOTES:
(a) GRIP LENGTH - FROM UNDER SIDE OF HEAD TO END OF FULL CYLINDRICAL PORTION OF SHANK
(b) ANGLE - UNDER SIDE OF HEAD TO SHANK - 90° ± 1/2°, .001
(c) MAXIMUM SURFACE ROUGHNESS (PER MIL-STD-10): HEAD TO SHANK FILLET, THREAD ROOT, THREAD SIDES, THREAD RUN-OUT 16; SHANK AND BEARING SURFACE OF HEAD 63; ALL OTHER SURFACES 125
(d) CONCENTRICITY - "A", "B", AND "D" DIMENSIONS WITHIN "X" VALUES TIR
"D" AND "J" DIMENSIONS WITHIN "Y" VALUES TIR
"A" AND THREAD PITCH DIMENSIONS WITHIN "Z" TIR
(e) BOLTS SHALL BE FREE FROM BURRS AND SHARP EDGES

MATERIAL: 6AL-4V ONLY, PER NAS 621
FINISH: NO PROTECTIVE FINISH REQUIRED
CODE: PROFILE DASH NUMBER WITH "H" TO DESIGNATE DRILLED HEAD BOLT
EXAMPLES: NAS 1271-8 = 1/4 DIA BOLT, .500 GRIP, UNDRILLED HEAD
NAS 1271H8 = 1/4 BOLT, .500 GRIP, DRILLED HEAD

DIMENSIONS IN INCHES

INDEX OF CURRENT PAGES	
SHEET NO	REV. NO.
1	1
2	1

① TECHNICALLY UPDATED

CUSTODIAN NATIONAL AEROSPACE STANDARDS COMMITTEE

PROCUREMENT SPECIFICATION	TITLE	CLASSIFICATION
NAS 621	BOLT, TWELVE POINT, EXTERNAL WRENCHING, TITANIUM ALLOY	STANDARD PART NAS 1271 thru 1280 Sheet 1 of 2

APPROVAL DATE March 1960 REVISION ① 31 Jan. 1963

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NATIONAL AEROSPACE STANDARD

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC. 610 SHOREHAM BUILDING WASHINGTON 5 D C

DASH NO.	GRIP	LENGTH NAS 1271 1/4	NAS 1272 5/16	NAS 1273 3/8	NAS 1274 7/16	NAS 1275 1/2	NAS 1276 9/16	NAS 1277 5/8	NAS 1278 3/4	NAS 1279 7/8	NAS 1280 1
4 [illegible]	[illegible] .375 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 1.126 [illegible]	[illegible]	[illegible]	1.367 [illegible]	[illegible]	1.892
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.132 2.257 2.382
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 2.757 [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 7.007
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.132 7.257 7.382 [illegible]
[illegible]	[illegible]						[illegible]	[illegible]	[illegible] 7.918	[illegible]	[illegible] 7.757 [illegible]
[illegible] 112	[illegible] 7.000						7.575 7.701 7.826	[illegible] 7.748 7.873	[illegible] 7.993	[illegible] 8.196	8.132 8.257 8.382

DASH NUMBERS SHOWN ARE PREFERRED LENGTHS IN .125 INCREMENTS. INTERMEDIATE OR LONGER LENGTHS IN .062 INCREMENTS MAY BE OBTAINED BY SPECIFYING WHOLE DASH NUMBERS.

① TECHNICALLY UPDATED

CUSTODIAN NATIONAL AEROSPACE STANDARDS COMMITTEE

PROCUREMENT SPECIFICATION	TITLE	CLASSIFICATION
NAS 621	BOLT, TWELVE POINT, EXTERNAL WRENCHING, TITANIUM ALLOY	STANDARD PART NAS 1271 thru 1280 Sheet 2

APPROVAL DATE March 1960 REVISION ① 31 Jan. 1963

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TABLE II. SHANK STRAIGHTNESS

NOMINAL SHANK DIA	MAXIMUM DEVIATION (INCHES PER INCH OF LENGTH)
.312 and under	.0030
.313 to .499	.0025
.500 and larger	.0020

3.4 Mechanical Properties

Mechanical properties of fasteners shall conform to the following requirements.

3.4.1 Ultimate Tensile Strength

When tested and evaluated in accordance with 4.6.2.1 the ultimate tensile strength shall conform to the requirements of Table III. Tensile tests are not applicable to threaded fasteners whose nominal length is less than twice the diameter, to [illegible] threaded fasteners with nominal grip less than 3/4 of nominal diameter, nor to tension lockbolts having nominal grip less than 1-1/2 times nominal diameter.

3.4.2 Ultimate Double Shear Strength

When tested and evaluated in accordance with 4.6.2.2 the ultimate double shear strength shall conform to the requirements of Table III. Shear tests are not applicable to protruding head fasteners whose nominal grip is less than twice the nominal diameter, nor to flush head fasteners whose nominal grip is less than 2-1/2 times the nominal diameter.

3.4.3 Fatigue Life

When tested and evaluated in accordance with 4.6.2.4 the fatigue life shall conform to the applicable acceptance standard. Fatigue tests are not applicable to threaded fasteners smaller than size 10 (.190), to fasteners having a grip less than twice the nominal diameter nor to fasteners with drilled or cut holes in threads.

3.5 Metallurgical Properties

Metallurgical properties of fasteners shall conform to the following requirements. Examination shall be conducted in accordance with 4.6.3.

TABLE III. SHEAR AND TENSILE PROPERTIES

SIZE OF FASTENER	SHEAR – ALL FASTENERS: ULT. DOUBLE SHEAR (LB)	SHEAR – LOAD RATE	TENSILE – ULT. TENSILE A	TENSILE – ULT. TENSILE B	LOAD RATE	ULTIMATE TENSILE 1	ULTIMATE TENSILE 2	TEST FIXTURE	SHANK [illegible]	TEST [illegible] A	TEST [illegible] B
[illegible] [illegible] .112	- - [illegible]	- - [illegible]	- - -	[illegible]	[illegible]	- - -	- - -	- - -	- - -	- - -	- - -
.138 .156 .164	[illegible] - 4000	[illegible]	- - -	[illegible]	[illegible]	[illegible]	- - -	[illegible]	- - -	- - -	- - -
.190 .250 .312	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.375 .437 .500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] - -	- -	[illegible] - -	[illegible]	[illegible]	[illegible] - -
.562 .625 .750	[illegible]	[illegible] 4400	[illegible]	[illegible]	[illegible]	- - -	- - -	- - -	- - -	- - -	- - -
.875 1.0-12 1.0-14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	- - -	- - -	- - -	- - -	- - -	- - -

NOTES: (a) Test with nut or threaded adapter (See Figure 5).

(C) Completely Revised

NAS 621 Sheet 6

APPROVAL DATE [illegible] REVISION [illegible] (1) [illegible] (1) 15 Dec. 1955 (5) 30 Jan. 1971

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NATIONAL AEROSPACE STANDARD
AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC. 1725 DE SALES STREET N W WASHINGTON D C 20036

3.5.1 Cracks

There shall be no cracks in any location. A crack is defined as a clean, crystalline break passing through grain or grain boundry, without inclusion of foreign elements.

3.5.2 Discontinuities

Laps, seams and similar surface irregularities are permitted in some locations as shown in Figure 4, and the following, only if depths do not exceed the specified values. A surface irregularity consisting of folded or lapped metal shall be defined as a lap only, if it appears in two or more consecutive pitches of the thread profile in cross section, or in both sides (180° apart) of a groove cross section.

3.5.2.1 Flank

Irregularities are permissible on the non-pressure flank of threads or grooves as tabulated in Figure 4.

3.5.2.2 Crests

Surface irregularities are permitted in the crest of threads or grooves to the depth tabulated in Figure 4.

3.5.2.3 Roots

Laps are not permitted in the roots of threads and grooves, except that in thread sizes number 6 (.138) and smaller, laps whose depths do not exceed .0015 inch are acceptable in the three pitches nearest the head, including the runout.

3.5.2.4 Non-Bearing Surfaces of Head

[illegible] nicks and gouges are acceptable on non-bearing surfaces of the head if their depth does not exceed twice the value tabulated in Figure 4.

3.5.2.5 Head Bearing Surface

[illegible] permitted in the head bearing surface and in the grip or shank area providing the depth does not exceed Figure 4 values and that they do not extend into head-shank fillet, or into threads.

3.5.3 [illegible] and Surface Contamination

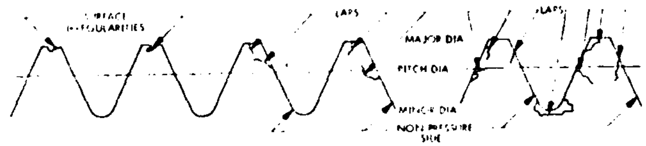
[illegible] and surface contamination are permitted in [illegible] and on non-bearing surfaces of heads to a maximum depth of [illegible].

3.5.4 Heat Treatment

Fasteners shall be heat treated to provide the tensile, shear and fatigue properties [illegible] the required metallurgical properties required herein. Production parts shall be heat treated in the manner [illegible] Certification [illegible] 4.2.1.

3.5.5 Microstructure and Overheating

[illegible] shall be free from [illegible] alloy segregation. [illegible]
[illegible] A-286 alloys [illegible] considered overheated.



FASTENER DIA	.060	.086	.112	.138	.156	.164	.190	.250	.312	.375	.437	.500 and Larger
DISCONTINUITY DEPTH	.004	.004	.004	.004	.004	.005	.005	.005	.005	.006	.007	.006

FIGURE 4. DISCONTINUITIES

(A) Completely Revised

NAS 621 Sheet 7

APPROVAL DATE [illegible] REVISION [illegible] 30 Jan. 1971

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I,17

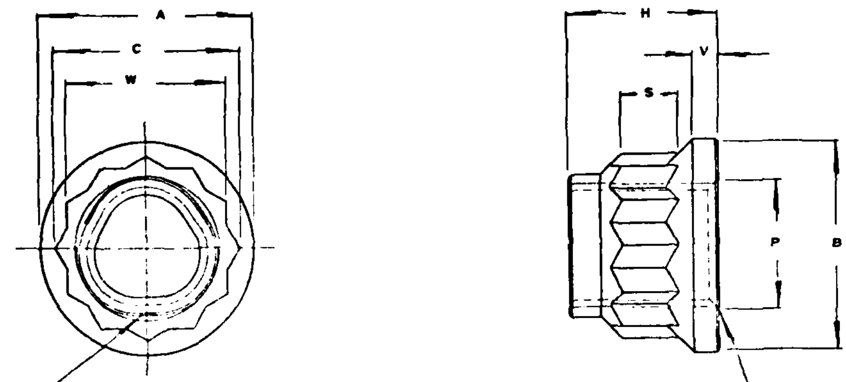
I.18

SPS STANDARD PRESSED STEEL CO.

SHEET 1 OF 1

DRAWING NUMBER SPS-N-59715

REVISION: (2) REVISED AND REDRAWN 12/10/64 (3) 8-8-66 (4) 4 24 67 (5) 2-7-68 (6) 7-12-68



TOOL MARKS AND DISTORTION AT TOP OF NUT DUE TO LOCKING FEATURE PERMISSIBLE.

COUNTERSINK, COUNTERBORE, OR RADIUS RELIEF TO THREAD WITHIN THE LIMITS OF P DIAMETER

PART NUMBER	(1) THREAD SIZE	A MAX.	B MIN.	C MIN.	H MAX.	P MAX.	S MIN.	V MIN.	W MAX.	W MIN.	(2) X	(3) Y	AXIAL STRENGTH LBS. MIN.	WEIGHT MAXIMUM LBS. 100
FNT20-1032	.190-32 UNJF-3B	.350	.320	.277	.230	.220	.080	.020	.251	.243	.003	.002	4,000	.15
FNT20-428	.250-28 UNJF-3B	[illegible]	.403	.347	.303	[illegible]	[illegible]	.027	.313	.305	.003	.002	7,270	.27
FNT20-524	.312-24 UNJF-3B	[illegible]	.501	.419	.365	.347	[illegible]	.042	.376	.367	.004	.002	11,600	.50
FNT20-624	.375-24 UNJF-3B	[illegible]	.619	.431	[illegible]	.435	.152	.027	.431	.430	.005	.002	17,600	.85
FNT20-720	.437-20 UNJF-3B	[illegible]	.720	.551	.520	.473	.163	.078	.564	.553	.005	.003	23,700	1.45
FNT20-820	.500-20 UNJF-3B	.828	.798	.703	.600	.535	.190	.092	.627	.616	.006	.003	32,000	2.08
FNT20-918	.562-18 UNJF-3B	.938	.909	.775	.680	.597	.230	.100	.690	.679	.008	.003	40,600	2.76
FNT20-1018	.625-18 UNJF-3B	1.050	1.020	.835	.742	[illegible]	[illegible]	.110	.752	.741	.008	.003	51,200	3.56

(1) THREADS: BEFORE LUBRICATION PER MIL-S-8879.
(2) BEARING SQUARENESS: BEARING SURFACE TO BE SQUARE WITH PITCH DIAMETER WITHIN X WHEN CHECKED AT A POINT MIDWAY BETWEEN THE I.D. AND O.D. OF THE BEARING SURFACE.
(3) BEARING FLATNESS: BEARING SURFACE TO BE FLAT TO CONCAVE WITHIN Y T.I.R. WHEN CHECKED IN ACCORDANCE WITH SPS-G-1013.

MATERIAL: TITANIUM ALLOY PER AMS 4928.

• LUBRICANT: DRY FILM LUBRICANT.

FLUORESCENT PENETRANT INSPECT 100% PER SPS-N-269.

BREAK SHARP CORNERS.

DIMENSIONS IN INCHES.

DIMENSIONS TO BE MET PRIOR TO LUBRICATION

• SURFACE TEXTURE: USAS B46.1 UNLESS OTHERWISE SPECIFIED THE SURFACE TEXTURE SHALL NOT EXCEED 125 MICROINCHES.

PERFORMANCE: SEE PROCUREMENT SPECIFICATION.

DESIGN AND USAGE LIMITATIONS: THESE NUTS ARE DESIGNED TO DEVELOP THE TENSILE STRENGTH OF BOLTS AND SCREWS WITH AN ULTIMATE TENSILE STRENGTH OF 200 KSI BASED ON THE TENSILE STRESS AREA OF THE EXTERNAL THREAD. THESE NUTS ARE DESIGNED TO BE USED ON CLASS 3A EXTERNAL THREADS WITHIN THE LIMITATIONS OF MS 33538. THESE NUTS ARE RECOMMENDED FOR USE ON EWB T815 BOLTS.

THIS STANDARD TAKES PRECEDENCE OVER DOCUMENTS REFERENCED HEREIN. REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

PART NUMBERS OTHER THAN LISTED ON THIS DRAWING SHALL NOT BE USED.

STANDARD

TOLERANCES + ——— AND ——— UNLESS OTHERWISE NOTED

• INDICATES LATEST CHANGE

STANDARDS AND SPECIFICATIONS: SPS-N-269, CLASS II	TITLE: NUT, FLEXLOC, DOUBLE HEXAGON, SELF-LOCKING, TITANIUM 750°F, 200 KSI, FLANGED	DRAWN BY W. A. B. DATE 3/15/63
FED. IDENT. CODE NO. 56878		APPROVED DATE 3/15 63
CUSTODIAN JENKINTOWN, PENNA.		PART NUMBER FNT 20

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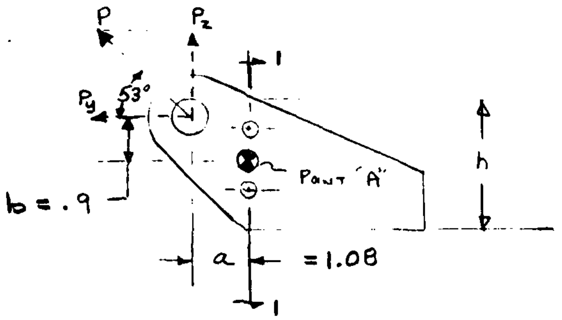
SKETCH NO. I.19

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE ______

SIDE BRACE ATTACHMENT
ANALYSIS

STRESSES AT SECTION 1-1



h = 3.3 in

t = PART THICKNESS = .560

LAY UP : [0, ±45, 90] WITH 0° PLY ‖ to P_y LOAD. PROPERTIES SHOWN IN P. I.21 .

LOADS

$$P = 70\% \times F_{SB} = .7\,(11{,}619) = 8{,}133^{\#}$$

$$P_z = P \sin 53° = 8133\,(.7986) = 6{,}495^{\#}$$

$$P_y = P \cos 53° = 8133\,(.6018) = 4{,}894^{\#}$$

SHEAR STRESS

$$\tau = \frac{3}{2}\frac{P_z}{A} = 1.5\,\frac{(6{,}495)}{t\,h} = \frac{9743}{(.56)(3.3)} = \underline{\underline{5{,}260}}\ \text{PSI}$$

DESIGN ALLOWABLES

BASED UPON $\tau_{ult} = 5{,}260$

$$\tau_{LIMIT} = \frac{\tau_{ult}}{1.2} = 4{,}390\ \text{PSI}\ \ (\text{USE } 5{,}000)$$

AND FROM CURVE ON PAGE I. 21

PROPERTY	LIMIT	ULT
τ	5000	7000
F_{xt}	30,000	36,000
F_{xc}	40,000	48,000
F_{yt}	10,000	12,000
F_{yc}	20,000	24,000

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SKETCH NO. I.20

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR gnB

BLDG. ______ TITLE ______

BENDING AND NORMAL STRESSES

$$F_N = \frac{P_y}{A} = \frac{4{,}894}{t\,h} = \frac{4{,}894}{1.85} = 2{,}640 \text{ PSI}$$

$$F_b = \frac{Mc}{I} = \frac{6\,m}{t\,h^2} = \frac{6\left[P_z\,a - P_y\,b\right]}{.56\,(3.3)^2}$$

$$= .985\left[6495(1.05) - 4894(.9)\right] = 2{,}560 \text{ PSI}$$

$$F_t = 2{,}640 \pm 2560 = \underline{\underline{+5200 \text{ PSI}}}, \quad 80 \text{ PSI}$$

$$m.s. = \frac{F_{xt}}{5200} - 1 = \underline{\underline{+5.93}}$$

DESIGN PROPERTIES (77° F)
FOR
~~2002~~ 2525 AS GRAPHITE EPOXY LAMINATE [$0°_2$/±45°]
55 % FIBER VOL.

ELASTIC CONSTANTS

E_x = 11.03 × 10^6 PSI

E_y = 2.45 × 10^6 PSI

μ_x = 0.65

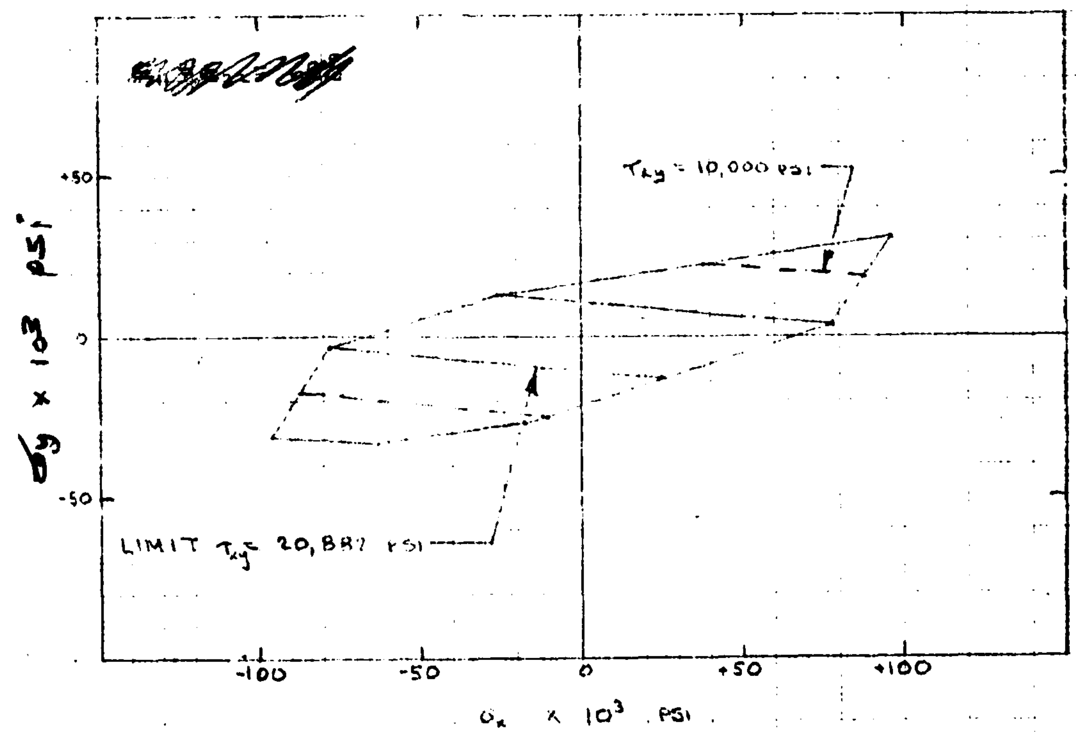
G_{xy} = 2.11 × 10^6 PSI

THERMAL COEFFICIENTS

α_x = −0.345 IN/IN/°F × 10^{-6}

α_y = +4.116 IN/IN

"LIMIT" INTERACTION CURVE



ERT
1-31-73

DESIGN PROPERTIES (70°F)

FOR:

2002 AS ($\epsilon_{11} = \epsilon_{22} = .69\%$) / 60% GRAPHITE FIBER VOL.

[0°/+45°/90°], SAME AS [0°, +45°] WITH $\phi = +45°$

QUASI - ORTHOTROPIC

ELASTIC CONSTANTS

$E_x = 6.70 \times 10^6$ psi

$E_y = 6.70 \times 10^6$ psi

$\mu_{xy} = 0.087$

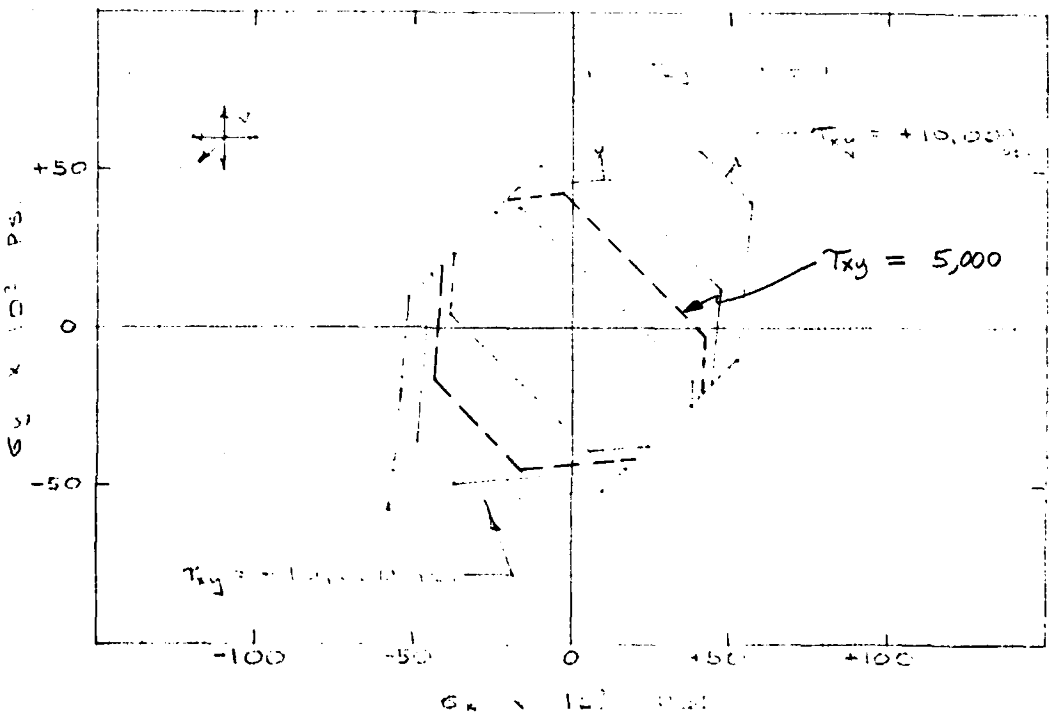
$G_{xy} = 1.49 \times 10^6$ psi

THERMAL COEFFICIENTS

$\alpha_x = 1.123$ in/in/°F $\times 10^{-6}$

$\alpha_y = 1.123$ in/in/°F $\times 10^{-6}$

INTERACTION CURVE



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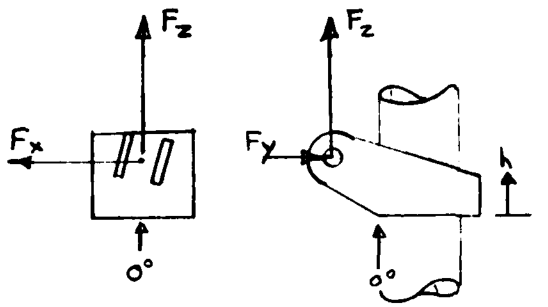
SKETCH NO. I.22

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE A-37 B LANDING GEAR

SIDE BRACE ATTACHMENT
SHEAR STRESSES IN BOND
TO TUBE

} TENSILE LOAD, COND. 3A



F_z = 9000 #
F_x = -1000 #
F_y = -7300 #

h = HEIGHT AT 0° = 3.0 IN

ULT. ALLOWABLE SHEAR = 4750 PSI AT R.T. FOR HYSOL'S EA 9309

SHEAR DUE TO F_z @ 0°

$V_{max} = F_z \, C_{v_p}$ $\qquad C_{v_p} = .5$ FROM CURVE ON P. I.23

$= 9000\,(.5) = 4500$ #/IN

$\tau_z = \dfrac{V_{max}}{h} = \dfrac{4500}{3} = 1500$ PSI at 0°

SHEAR DUE TO F_x @ 0°

$V_{max} = \dfrac{4\,F_x}{\pi R} = \dfrac{4\,(1000)}{\pi\,(2)} = 638$ #/IN

$\tau_x = \dfrac{638}{3} = 212$ PSI

COMBINED SHEAR @ 0°

$\tau_T = \left[\tau_x^2 + \tau_z^2\right]^{1/2} = \left[(212)^2 + (1500)^2\right]$

$= \underline{\underline{1510 \text{ PSI}}}$

$\text{M.S.} = \dfrac{4750}{1500} - 1 = \underline{\underline{+2.17}}$

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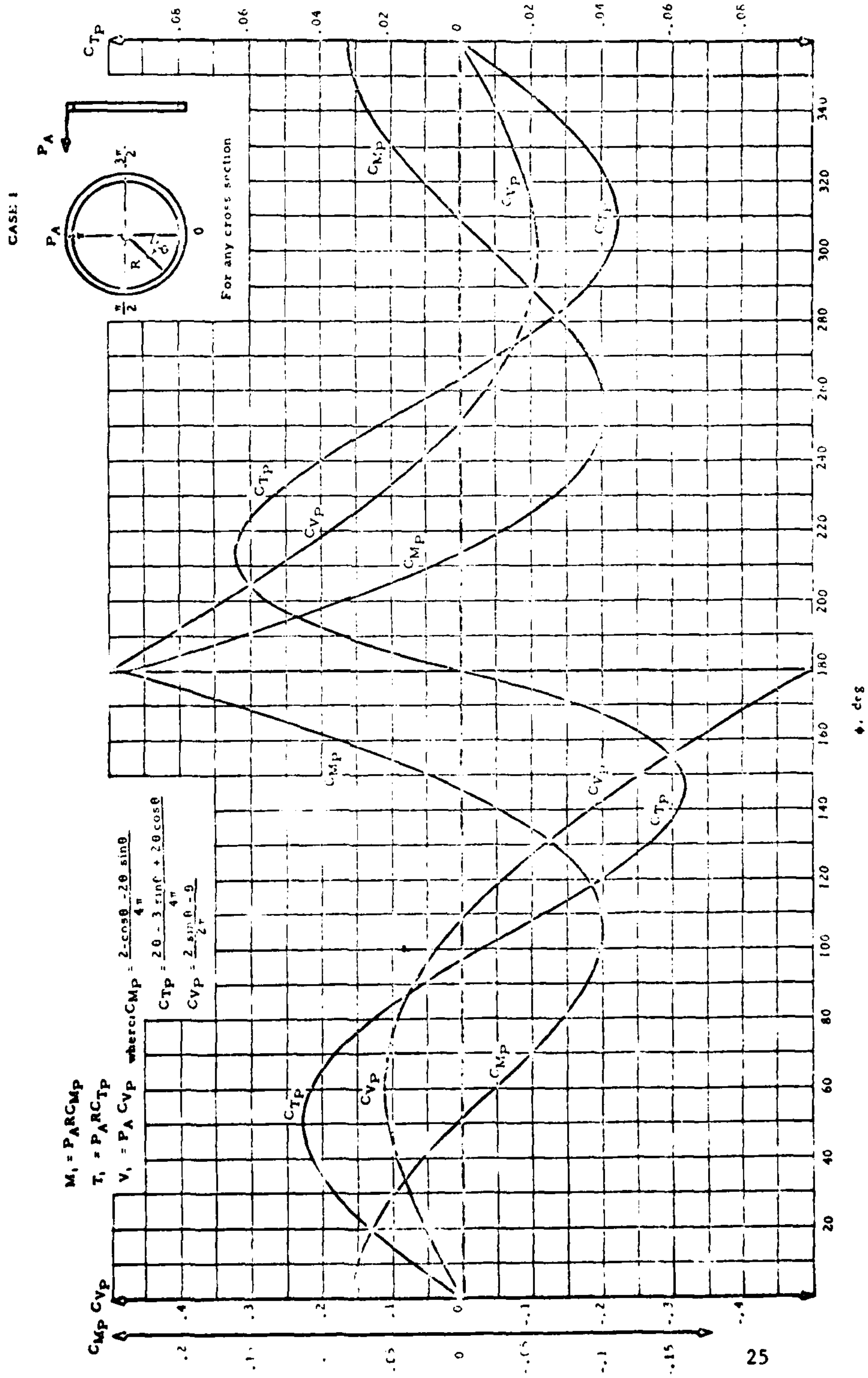
SKETCH NO. I.23

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE A-37 B LANDING GEAR



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SKETCH NO. I.24

PLANT ________ PROJECT NO. ________ DATE 2-73 AUTHOR JMB

BLDG. ________ TITLE A-37 B LANDING GEAR

SIDE BRACE ATTACHMENT
SHEAR STRESSES IN BOND
TO TUBE

} COMPRESSIVE LOAD, COND. 6A

SEE FIGURE P. I.22

$F_z = -22,700$

$F_x = 2600$

$F_y = 18,400$

$h = 3.0$

ULT. SHEAR ALLOWABLE = 4750 PSI
EA-9309

SHEAR DUE TO F_z

$$V_{max_y} = F_z C_{vp} = 22,700 (.5) = 11,350 \ \#/IN$$

$$\tau_y = \frac{V_{max}}{h} = \frac{11,350}{3.5} = 3,240 \text{ PSI}$$

SHEAR DUE TO F_x

$$V_{max_x} = \frac{4 F_x}{\pi R} = \frac{4 (2600)}{\pi (2)} = 1650 \ \#/IN$$

$$\tau_x = \frac{1650}{h} = \frac{1650}{3.5} = 470 \text{ PSI}$$

COMBINED SHEAR

$$\tau_T = \left[\tau_x^2 + \tau_y \right]^{\frac{1}{2}} = \left[(3240)^2 + (470)^2 \right]^{1/2}$$

$$\tau_T = \underline{\underline{3280 \text{ PSI}}}$$

$$m.s. = \frac{4750}{3280} - 1 = \underline{\underline{+0.45}}$$

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SKETCH NO. I.25

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JWB

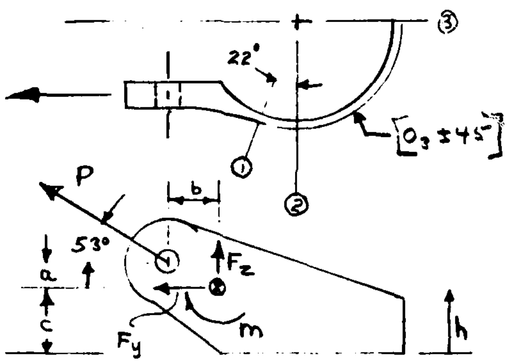
BLDG. ______ TITLE ______

SIDE BRACE ATTACHMENT
STRESSES IN BAND

FROM P. I.26
ULT. ALLOWABLES $[0_3 \pm 45]$

$\sigma_x = 72{,}000$ $\sigma_y = 12{,}000$

$\tau_{xy} = 20{,}000$ INTERLAMINAR SHEAR $= 12{,}000$



$h_{\otimes} = 3.7$

$h_1 = 3.1$ $t_1 = .140$

$h_2 = 2.7$ $t_2 = .140$

$h_3 = 1.75$ $t_3 = .140$

$a = 1.38$

$b = 1.08$

$P = 70\%\ F_{SB}$

$+P = 70\%\,(11{,}619) = +8{,}133^{\#}$

$-P = 70\%\,(29{,}306) = -20{,}514^{\#}$

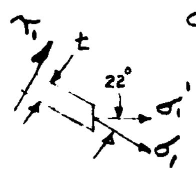
$c = 1.6$

STRESSES DUE TO $+P = 8133$

$F_y = P\cos 53° = 4895^{\#}$ $F_z = P\sin 53° = 6495^{\#}$

$m = aF_y - bF_z = -260''^{\#}$

@ ①



$$\sigma_1 = \frac{\sigma_1'}{\cos 22°} = 1.078\ \sigma_1$$

$$t_1' = \frac{t_1}{\cos 22°} = \frac{.140}{.927} = .151$$

$$\sigma_1 = 1.078\left[\frac{F_y}{t_1' h_1} + \frac{6m}{t_1' h_1^2}\right] = 1.078\left[10{,}459 + 1075\right]$$

$\sigma_1 = 12{,}433$ PSI

$$\tau_1 = \cos 22\ \sigma_1' = \cos^2 22\ \sigma_1 = .859\,(12{,}433) = 10{,}683 \text{ PSI}$$

$$\text{m.s.} = \frac{12{,}000}{10{,}680} - 1 = \underline{\underline{+0.123}}$$

DESIGN PROPERTIES (77° F)
FOR
AS / 2002 GRAPHITE / .688 % ULT. RESIN [$0°_8$ / ± 45°]
55 % FIBER VOL.
QUASI – ORTHOTROPIC

ELASTIC CONSTANTS

E_x = 11.03 × 10^6 PSI

E_y = 2.45 × 10^6 PSI

μ_x = 0.65

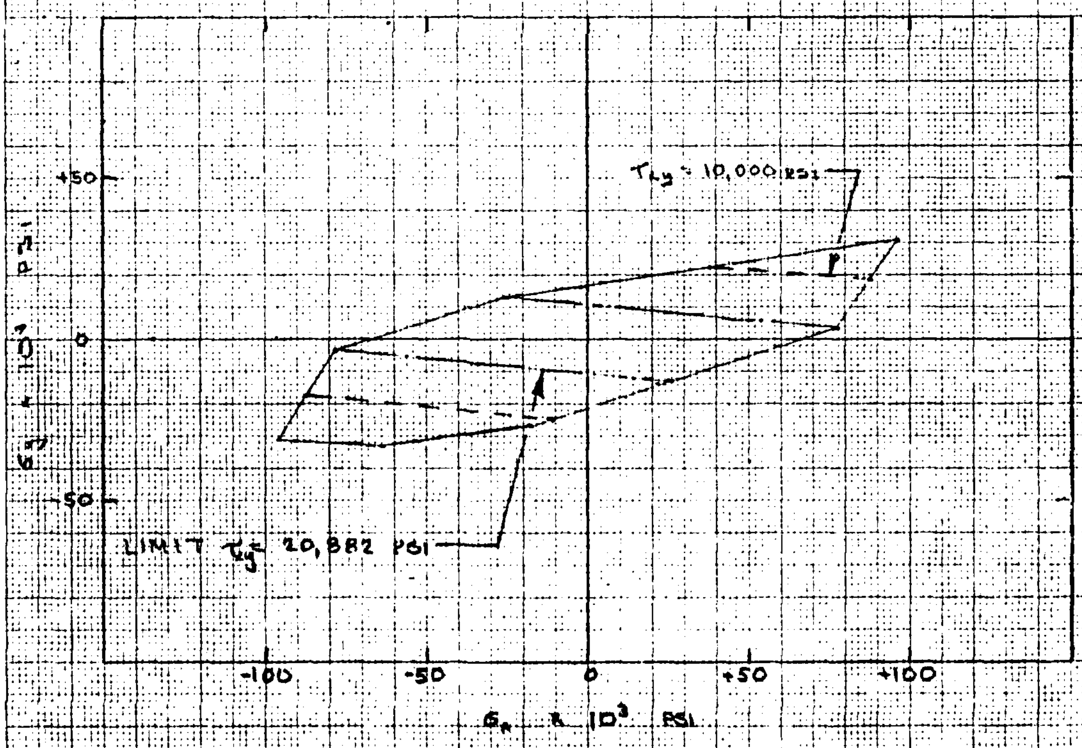
G_{xy} = 2.11 × 10^6 PSI

THERMAL COEFFICIENTS

α_x = – 0.345 IN/IN/°F × 10^{-6}

α_y = + 4.116 IN/IN

"LIMIT" INTERACTION CURVE



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SKETCH NO. I, 27

PLANT ______ PROJECT NO. ______ DATE 273 AUTHOR JRB

BLDG. ______ TITLE ______

AT ②

$$\sigma_2 = \frac{F_y}{t_2 h_2} + \frac{6m}{t_2 h_2^2} + \frac{6\left[(F_y)\left(\frac{h_2}{2} - c\right)\right]}{t_2 h_2^2}$$

$$= \frac{4895}{(.140)(2.7)} \mp \frac{6(-260)}{(.140)(2.7)^2} \mp \frac{6\left[-1224\right]}{(.140)(2.7)^2}$$

$$= 12,950 \pm 1529 \mp 7,196 = \underline{\underline{21,674 \text{ PSI}}}$$

$$\text{m.s. } \frac{72,000}{21,674} - 1 = \underline{\underline{+2.32}}$$

$$\tau_2 = 0.0$$

AT ③

$$\sigma_3 = \frac{F_y}{t_3 h_3} \mp \frac{6m}{t_3 h_3^2} \mp \frac{6\left[F_y\left(\frac{h_3}{2} - c\right)\right]}{t_3 h_3^2}$$

$$= \frac{4895}{.245} \mp \frac{6(-260)}{.429} \mp \frac{6\left[4895(-.725)\right]}{.429}$$

$$= 19,980 \mp 3636 \mp 49,634$$

$$= \underline{\underline{73,250 \text{ PSI}}}$$

$$\text{m.s.} = \frac{72,000}{73,250} - 1 = \underline{\underline{-.017}}$$

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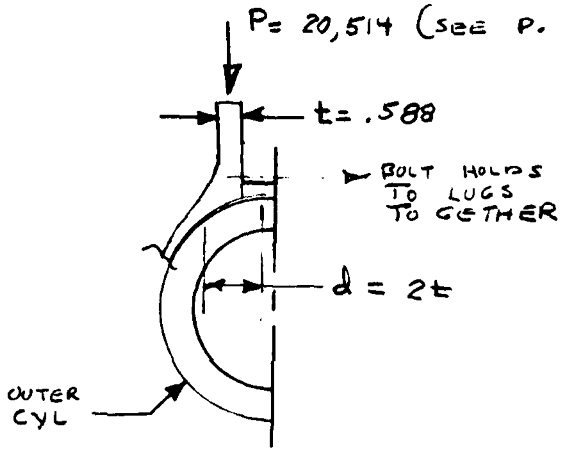
SKETCH NO. I.28

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE ______

SIDE BRACE ATTACHMENT
STRESSES IN BAND DUE
TO -P = 20,514



ASSUMPTION: BOLTS HOLD THE TWO LUGS TOGETHER AND THAT THE LOAD IS TRANSFERRED TO THE OUTER CYLINDER OVER DIMENSION d

$$\sigma = -\frac{F_y}{dh} \pm \frac{6m}{dh^2} = \frac{4895}{(1.18)(3.6)} \pm \frac{6(260)}{(1.18)(3.6)^2}$$

$$= -1152 \pm 102$$

$$= -1254 \text{ PSI}, \; -1050 \text{ PSI}$$

M.S. = HIGH

APPENDIX A
PART II

DESIGN AND ANALYSIS
OF
THE TORQUE ARM ATTACHMENT

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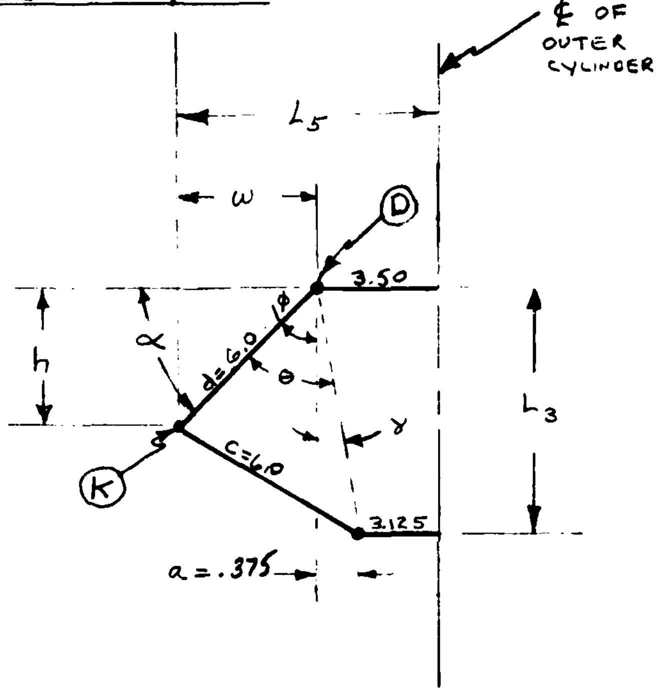
SKETCH NO. II - 1

PLANT ______ PROJECT NO. ______ DATE ______ AUTHOR ____

BLDG. ______ TITLE A-37-B LANDING GEAR

TORQUE ARM GEOMETRY



$$b = \left[(L_3)^2 + a^2\right]^{1/2}$$

$$\text{TAN } \gamma = a / L_3$$

$$\text{COS } \theta = b/2c = b/12$$

$$\phi = \theta - \gamma$$

$$\alpha = 90 - \phi$$

$$\omega = d \cos \alpha = 6 \cos \alpha$$

$$h = d \sin \alpha = 6 \cos \alpha$$

DIM.	FULLY EXTENDED	LANDING	STATIC	FULLY COMPRESSED
L_3	11.62	7.62	5.22	3.62
b	11.626	7.629	5.233	3.639
γ	1.848	2.817	4.109	5.194
θ	14.34	50.524	64.145	72.347
φ	12.49	47.707	60.036	67.153
α	77.51	42.293	29.964	22.847
ω	1.299	4.438	5.198	5.529
h	5.858	4.038	2.997	2.330
L_5	4.799	7.938	8.698	9.029

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SKETCH NO. II-2

PLANT ______ PROJECT NO. ______ DATE ______ AUTHOR JQ B

BLDG. ______ TITLE A-37 B LANDING GEAR

TORQUE ARM
LOADS

CRITICAL LOADS (PER BENDIX REPORT)

LANDING ~ LOAD CONDITION 2C , Y_K = +9700 #

STATIC ~ LOAD CONDITION 5A , Y_K = +8200 #

CRITICAL LOADS FOR GRAPHITE DESIGN

THE ABOVE LOADS WERE DEVELOPED BY BENDIX FOR L_5 VALUES (SEE P.) OF

L_5 = 8.0 , LANDING

L_5 = 8.74 , STATIC

THE L_5 VALUES FOR THE GRAPHITE GEAR ARE

L_5 = 7.938 , LANDING

L_5 = 8.698 , STATIC

AND THEREFORE RESULTING IN THE FOLLOWING DESIGN LOADS

LANDING ~ $Y_K = \frac{8.0}{7.938} \times 9700 = \underline{\underline{9,776}}$ #

STATIC ~ $Y_K = \frac{8.74}{8.698} \times 8200 = \underline{\underline{8,240}}$ #

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SKETCH NO. II-3

PLANT ________ PROJECT NO. ________ DATE ________ AUTHOR ________

BLDG. ________ TITLE ________

TORQUE ARM ATTACHMENT LOADS

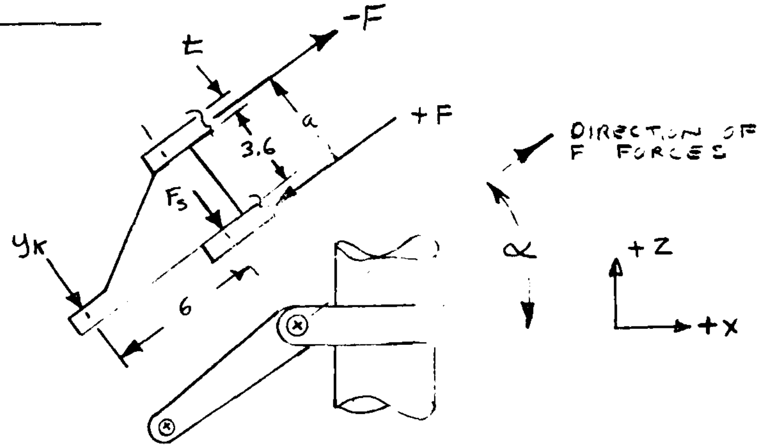
$t = .609$ (ASSUMED)

$a = 3.6 + t = 4.209$

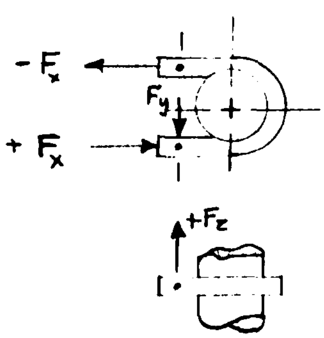
$m = 6\,Y_K$

$m = Fa$

$F = \frac{6\,Y_K}{a} = 1.425\,Y_K$



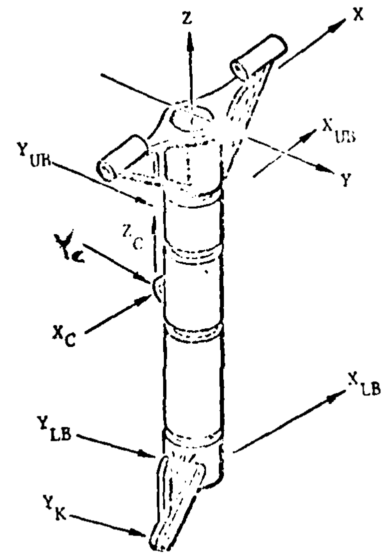
CONDITION	Y_K	F	F_s	α
LANDING (2C)	9776	13,931	9776	42.3
STATIC (5A)	8240	11,742	8240	30.0



		2C LANDING	5A STATIC
F_x	$= F\cos\alpha =$	10,303	10,168
F_z	$= F\sin\alpha =$	9,375	5,871
F_y	$= F_s =$	9,776	8,240

TABLE I

ULTIMATE LOADS APPLIED TO OUTER CYLINDER



OUTER CYLINDER

Load Conditions				X_{LB}	Y_{LB}	Y_K	X_C	Z_C	Y_C	X_{UB}	Y_{UB}
Landing Conditions	2 Pt. Level Landing	Max Vert	1A	-9500	-15300	5200	1100	-9300	7500	3900	10100
		Spin-up	1B	12100	3900	-6800	500	-4100	3300	-4800	2900
		Spring Back	1C	-16200	-18200	9100	900	-7600	6200	6400	9100
	Tail Down Landing	Max Vert	2A	-16000	-19400	9000	1000	-8900	-7230	6400	10400
		Spring Back	2C	-14900	-17000	9700	600	-5600	4600	4500	7200
	Drift Landing	Right	3A	-1400	6100	300	-1000	9000	-7300	500	-1800
		Left	3B	-1400	-21000	1600	2600	-22600	18300	500	13300
Static Conditions	Braked Roll		4A	14700	1300	-6100	700	-6300	5100	-7500	4800
	Reversed Brake		5A	-17900	-14000	8200	700	-6300	5100	8300	5800
	Right Turn		6A	-1800	-19100	1700	2600	-22700	18400	500	11600

Note: Loads in pounds.

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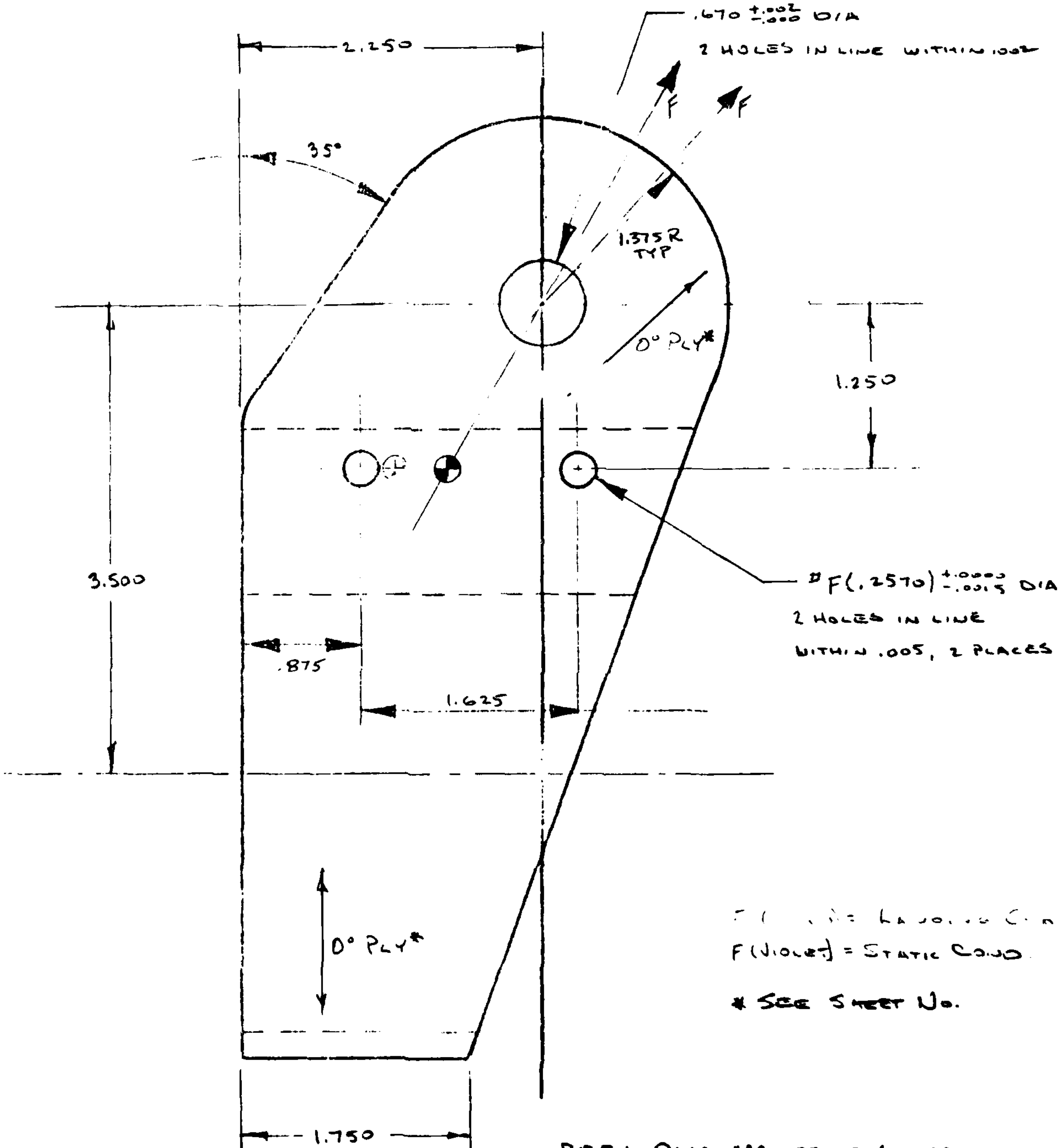
SKETCH NO. II-5

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37B Landing Gear - Torque Arm Attach



REF: DWG. NO. 830085'00432

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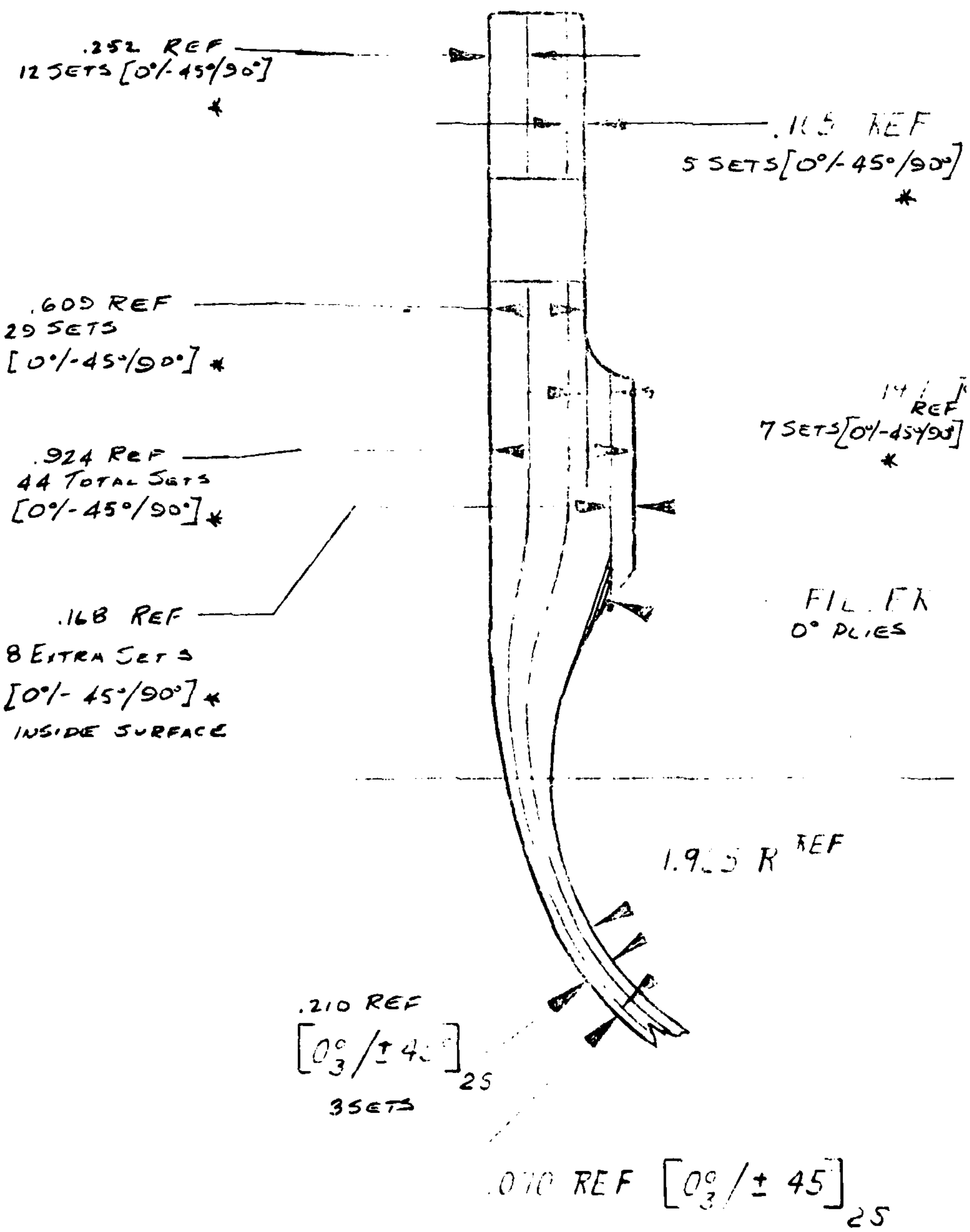
SKETCH NO. II-6

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR KRT

BLDG. ______ TITLE A-37B Landing Gear - Torque Arm Attach



* See next sheet

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SKETCH NO. II-1

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37 B Landing Gear - Torque Arm Attach

Ply Orientation At Band

[0°₃/±45°] Laminate

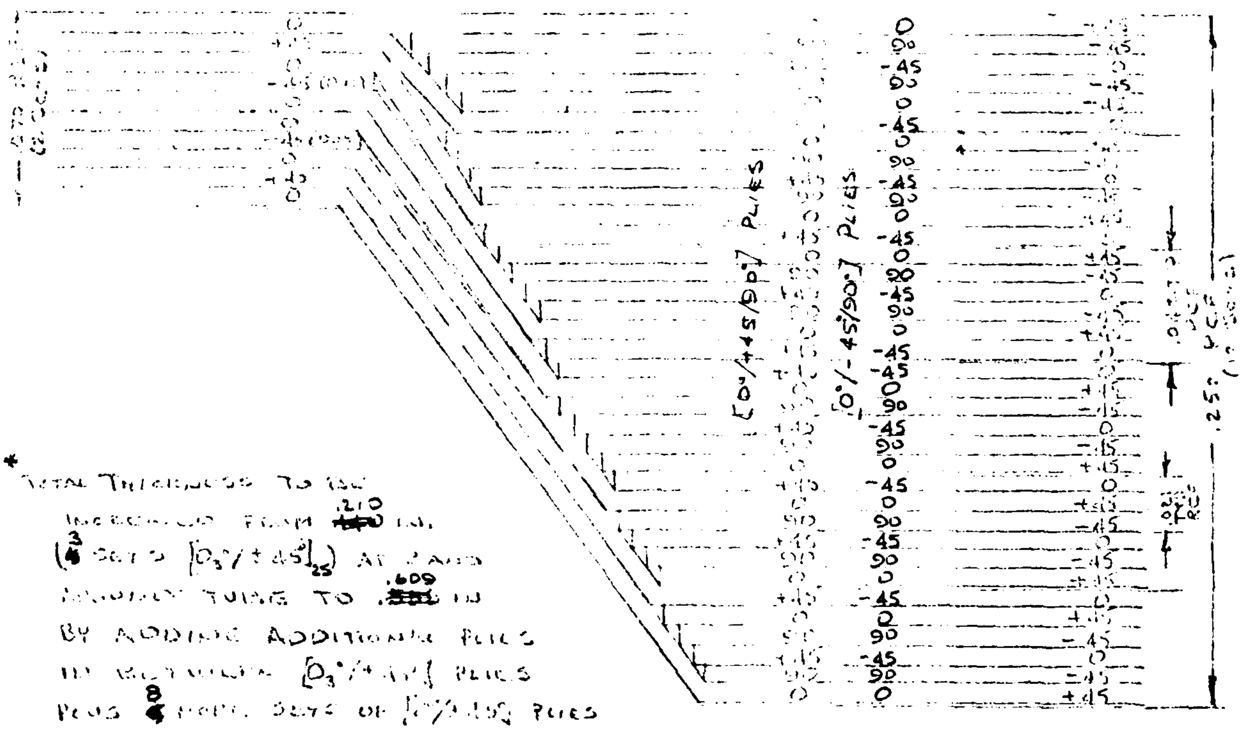
Actual Ply Orientation As Shown On Dwg No. 83008S00432

R.H. Lug

L.H. Lug

Ply Orientation For Lugs With Respect To Load

[0°/±45°] Laminate



* Total thickness to be increased from .210 in. (3 sets $[0_3^\circ/\pm45^\circ]_{25}$) at band around tube to .609 in by adding additional plies in between $[0_3^\circ/\pm45^\circ]$ plies plus 8 more sets of $[0^\circ/\pm45^\circ]$ plies (new orientation). The new orientation was set up with 0° ply parallel to + or − 45° with respect to the circumferential plies for analysis purposes. Dwg No 83008S00432 (Fig.) calls out the $[0^\circ/\pm45^\circ]$ as either $[0^\circ/+45^\circ/90^\circ]$ or $[0^\circ/-45^\circ/90^\circ]$ in order to be consistent with the nomenclature of the $[0_3^\circ/\pm45^\circ]$ plies.

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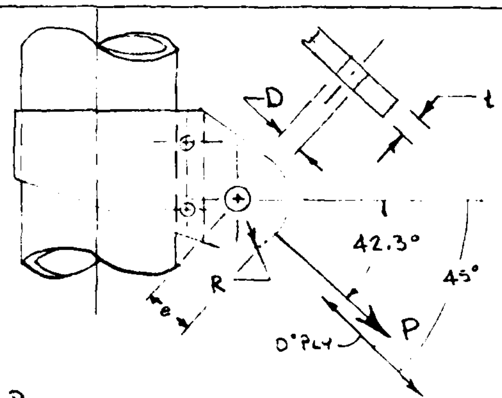
SKETCH NO. II - 8

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACH

TORQUE ARM ATTACHMENT
LUG ANALYSIS – TENSILE LOAD
LANDING (2c) LOAD CONDITION – CRITICAL



P DIRECTION CAN BE + OR – ; HOWEVER, DIRECTION SHOWN IS CRITICAL CONDITION.

LAY UP: $[0°/\pm 45°]_s$ WITH 0° PLY AS SHOWN

$P = F = 13{,}960\#$

$R = 1.375$ IN.

$D = .67$ IN.

$e = \left[R^2 - \left(\frac{D}{2}\right)^2\right]^{1/2} = \left[(1.375)^2 - \left(\frac{.67}{2}\right)^2\right]^{1/2} = 1.333$

$t = .609$ IN.

$s = R - .50 \times D = 1.375 - .335 = 1.040$ IN.

$s/D = \frac{1.040}{.67} = 1.552$

$e/D = \frac{1.333}{.67} = 1.991$

$D/t = \frac{.67}{.609} = 1.10$

$A_{br} = D \cdot t = .67 \times .609 = .408$

$A_t = (2R - D)t = (2 \times 1.375 - .67).609$

$A_t = 1.265$

$A_s = 2et = 2 \times 1.333 \times .609 = 1.623$

ASSUMING GRAPHITE TO STEEL MECH JOINT SINGLE LAP BEARING LOAD USING CURVE ON PG 239, REF 1, FOR $s/D = 2.63$.

ALLOWABLE BEARING STRESS

$F^{br} = 123{,}180$ PSI

$F^{br}_{ALLOWABLE} = 50\% \times F^{br} = .5 \times 123{,}180 = 61{,}590$ PSI

THIS FACTOR ACCOUNTS FOR FATIGUE AND UNCERTAINTIES IN F^{br} VALUES. F^{br} IN CURVE ON PG 6.2.65, REF 2 IS HIGHER ($F^{br} = 74{,}000$ PSI, DOUBLE SHEAR, $D/t = 1.10$).

REF: 1. ADVANCED COMPOSITE DATA FOR AIRCRAFT STRUCTURAL DESIGN, VOL III: MATERIAL & BASIC ALLOWABLE DEVELOPMENT – GRAPHITE/EPOXY, NORTH AMERICAN ROCKWELL / L.A. DIVISION, REPORT NO. AFML-TR-70-58, SEPT '72.
2. AIR FORCE DESIGN GUIDE.

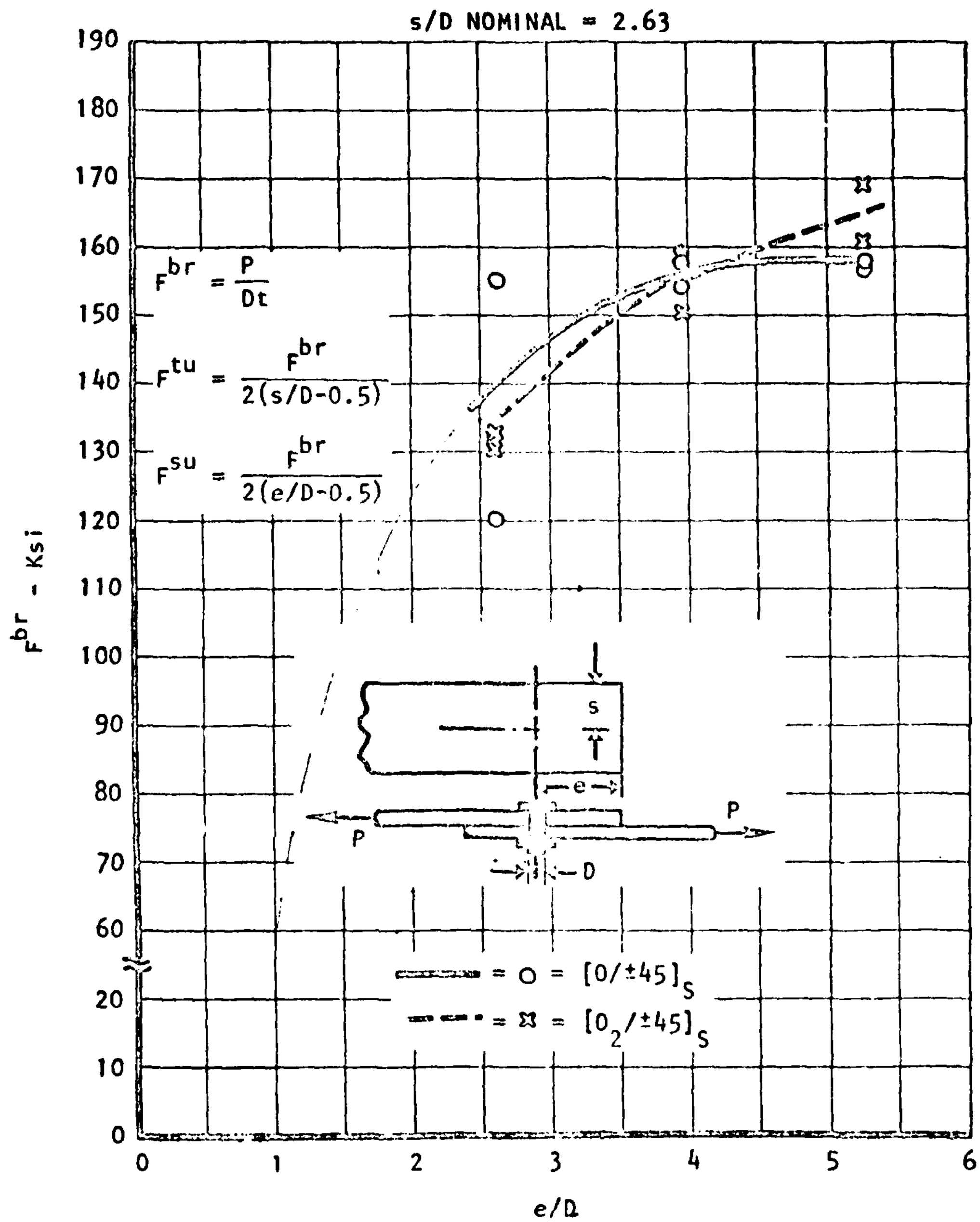


Figure 140. Graphite/Epoxy to Steel Mechanical Joint Single Lap Bearing Strength Versus e/D at Room Temperature (Type AS/3002, Batch) Protruding Head Fastener

REF : ADVANCED COMPOSITE DATA FOR AIRCRAFT STRUCTURAL DESIGN, VOL. IV : MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY, NORTH AMERICAN ROCKWELL /L.A DIVISION, REPORT # AFML-TR-70-58, SEPT. 1972

Graphite/epoxy data on equivalent bearing strength F^{br} versus D/t, for various laminate layup orientations of Narmco 5206, Type II, are presented in Figures 6.2.2.23 and 6.2.2.24, which were obtained from Reference 6.3. The design curves shown represent the lower bound data and are valid for the parameter range designated. Countersunk fastener joint data are presented in paragraph 6.2.2.1.2.

6.2.2.1.1.4 Elevated-Temperature Effects - The strength reduction in boron/epoxy test data for temperatures up to 375°F are shown in Figure 6.2.2.25 from References 6.2 and 6.25. The shearout, net-tension, and bearing temperature correction curves shown should be considered applicable only for the laminate orientations designated.

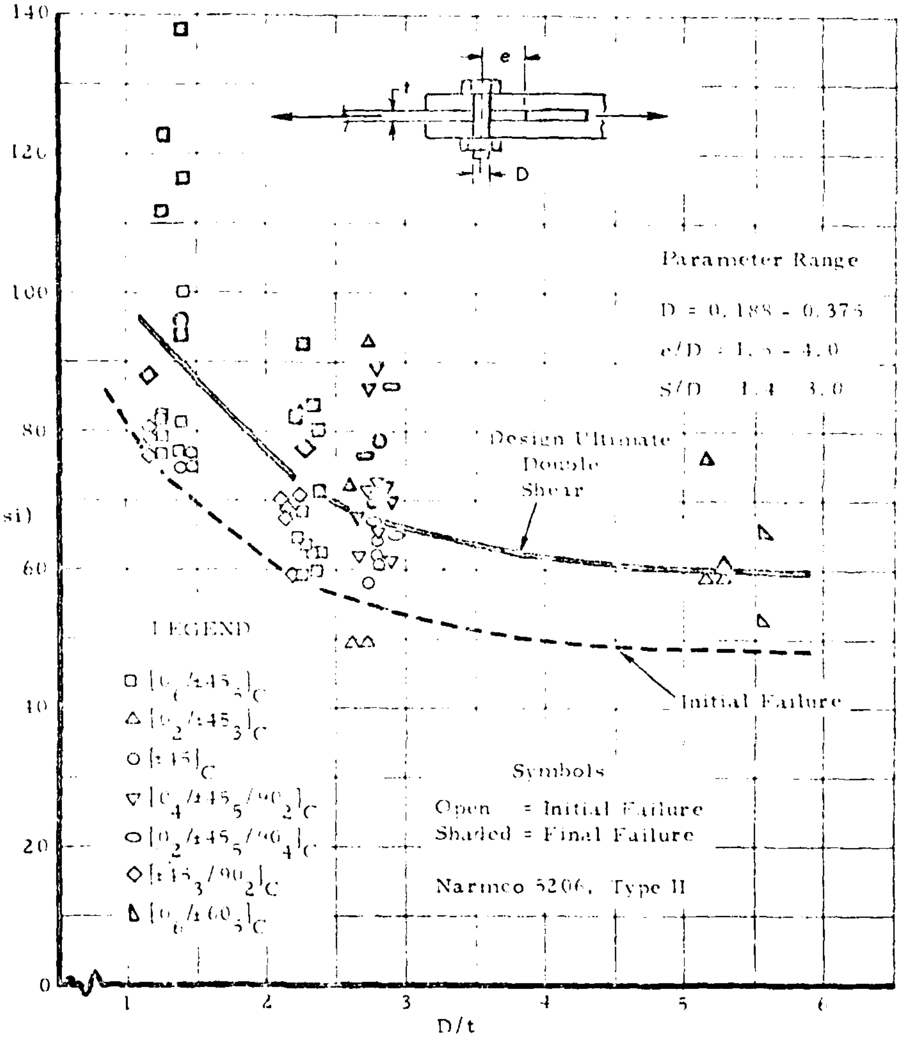


FIGURE 6.2.2.23. GRAPHITE/EPOXY MECHANICAL JOINT STRENGTH - DOUBLE SHEAR

TAKEN FROM AIR FORCE DESIGN GUIDE

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SKETCH NO. II-11

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37B LANDING GEAR – TORQUE ARM ATTACHMT

LUG ANALYSIS – TENSION, CONT'D

ALLOWABLE TENSILE STRESS

$$F^{tu}_{allowable} = \frac{F^{br}}{2(S/D - 0.5)} = \frac{61,590}{2(1.552 - .5)} = 29,300 \text{ PSI}$$

ALLOWABLE SHEAR TEAR-OUT STRESS

$$F^{su}_{allowable} = \frac{F^{br}}{2(e/D - .5)} = \frac{61,590}{2(1.991 - .5)} = 21,670 \text{ PSI}$$

CALCULATED STRESSES AND MARGINS OF SAFETY

BEARING

$$F^{br}_{calc} = \frac{P}{A_{br}} = \frac{13,960}{.408} = 34,200 \text{ PSI}$$

$$M.S. = \frac{61,590}{34,200} - 1 = +.801$$

TENSILE

$$F^{tu}_{calc} = \frac{P}{A_t} = \frac{13,960}{1.265} = 11,030 \text{ PSI}$$

$$M.S. = \frac{29,300}{11,030} - 1 = +1.656$$

TEAR-OUT SHEAR

$$F^{su}_{calc} = \frac{P}{A_s} = \frac{13,960}{1.623} = 8590 \text{ PSI}$$

$$M.S. = \frac{21,670}{8590} - 1 = +1.523$$

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SKETCH NO. II-12

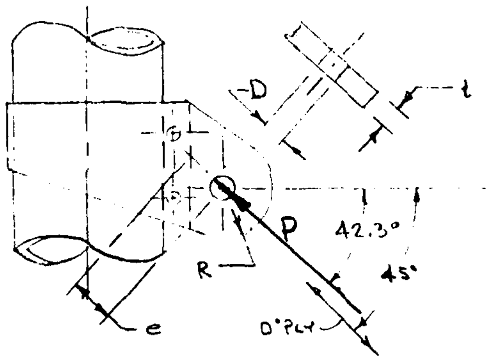
PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR E.R.T

BLDG. ______ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMT

LUG ANALYSIS, COMPRESSIVE LOAD

LANDING (2C) LOAD CONDITION - CRITICAL

MAGNITUDE AND ANGLE ARE SAME AS FOR TENSILE LOAD EXCEPT DIRECTION IS OPPOSITE TO THAT SHOWN ON PG



P DIRECTION CAN BE + OR - ; HOWEVER, DIRECTION SHOWN IS CRITICAL CONDITION.

LAY UP: $[0°/\pm45°]_s$ WITH 0° PLY AS SHOWN

$P = -F = -13{,}960\#$

$R = 1.375$ IN.

$D = .67$ IN

$e = \frac{.950 + 2.420}{2} = 1.685$ IN

$t = .609$ IN

$S = R - .5 \times D = 1.375 - .335 = 1.040$ IN

$S/D = \frac{1.040}{.67} = 1.552$

$e/D = \frac{1.685}{.67} = 2.516$

$D/t = \frac{.67}{.609} = 1.10$

$A_{br} = D \times t = .67 \times .609 = .408$

$A_t = (2R-D)t = (2 \times 1.375 - .67) \times .609 = 1.265$

$A_s = 2et = 2 \times 2.516 \times .609 = 3.065$

ALLOWABLE BEARING STRESS

USING CURVE ON PG FOR $e/D = 2.516$, ASSUMING COMPRESSIVE LOADING

$F^{br}_{ALLOWABLE} = \frac{F^{br}_{CURVE}}{2} = \frac{-138{,}000}{2} = -69{,}000$ PSI

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SKETCH NO. II-13

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37B Landing Gear - Torque Arm Attachmt

LUG ANALYSIS, COMPRESSIVE LOAD (CONT'D)

ALLOWABE COMPRESSIVE STRESS

$$F^{cu}_{ALL} = \frac{F^{br}_{ALL}}{2(s/D - .5)} = \frac{-69{,}000}{2(1.552 - .5)} = -32{,}795 \text{ PSI}$$

ALLOWABLE SHEAR TEAR OUT STRESS

$$F^{su}_{ALL} = \frac{F^{br}_{ALL}}{2(e/D - .5)} = \frac{-69{,}000}{2(2.516 - .5)} = -17{,}117 \text{ PSI}$$ (MAKE IT -10,000 PSI FOR INTERLAMINAR SHEAR)

CALCULATED STRESSES AND MARGINS OF SAFETY — COMPRESSIVE LOADS

BEARING

$$F^{brc}_{calc} = \frac{-13{,}960}{.408} = -34{,}200 \text{ PSI}$$

$$M.S. = \frac{-69{,}000}{-34{,}200} - 1 = +1.017$$

COMPRESSION

$$F^{cu}_{calc} = \frac{-13{,}960}{1.265} = -11{,}030 \text{ PSI}$$

$$M.S. = \frac{-32{,}795}{-11{,}030} - 1 = +1.973$$

INTERLAMINAR SHEAR

$$F^{s}_{calc} = \frac{-13{,}960}{3.065} = -4555 \text{ PSI}$$

$$M.S. = \frac{-10{,}000}{-4{,}555} - 1 = +1.195$$

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ENGINEERING DEPARTMENT

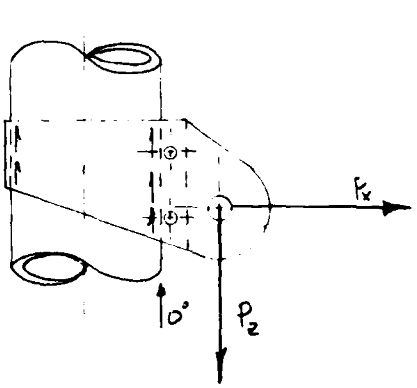
SKETCH NO. II-14

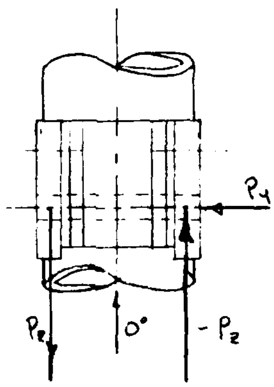
PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMT

TORQUE ARM ATTACHMENT
SHEAR STRESSES IN BOND TO TUBE

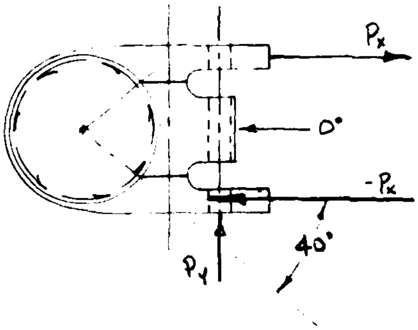
		2C LANDING	5A STATIC
CRITICAL LOAD CONDITION:	P_x =	10,303 #	10,168
	P_z	9,375	5,871
	P_y	9,776	8,240





LANDING COND IS WORST IN EA. CASE & WILL THEREFORE BE ANALYZED.

H = MEDIAN HEIGHT
= 2.4 IN



ULT. ALLOWABLE SHEAR = 4750 PSI
(AT R.T. FOR HYSOL'S EA #9309)

0° FOR P_z WILL BE ASSUMED TO BE 40° FROM ACTUAL 0° SO AS TO BE EFFECTIVE ON CLAMP. IT MAY NOT BE EFFECTIVE ON MIDDLE BLOCK.

FOR P_x, CASE 8, FIG. , PG APPLIES AND FOR P_z, CASE 1, FIG. , PG . APPLIES.

REF: ENG'G ANALYSIS — ANALYTICAL TECHNIQUES, VOL. I, APR. 1966

HERCULES INCORPORATED
ENGINEERING DEPARTMENT SKETCH NO. II-15

PLANT ________ PROJECT NO. ________ DATE 2-73 AUTHOR ERT

BLDG. ________ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMT

TORQUE ARM ATTACHMENT
SHEAR STRESSES IN BOND TO TUBE

SHEAR DUE TO P_z AT 40° (0°)

$C_{UP} = .50$, FROM CASE I CURVE

$H_{40°} = 2.92$ "

$V_{MAX} = P_z C_{UP} =$

$= 9375 \times .5 = 4688$ #/IN

$$\tau_z = \frac{V_{MAX}}{H_{e\,40°}} = \frac{4688}{2.92} = 1605 \text{ PSI}$$

SHEAR DUE T P_x AT 90°

$K_Q = .32$, FROM CASE 8 CURVE

$H_{90°} = 2.45$ "

$V_{MAX} = P_x \times K_Q = 10{,}303 \times .32$

$V_{MAX} = 3{,}297$ #/IN

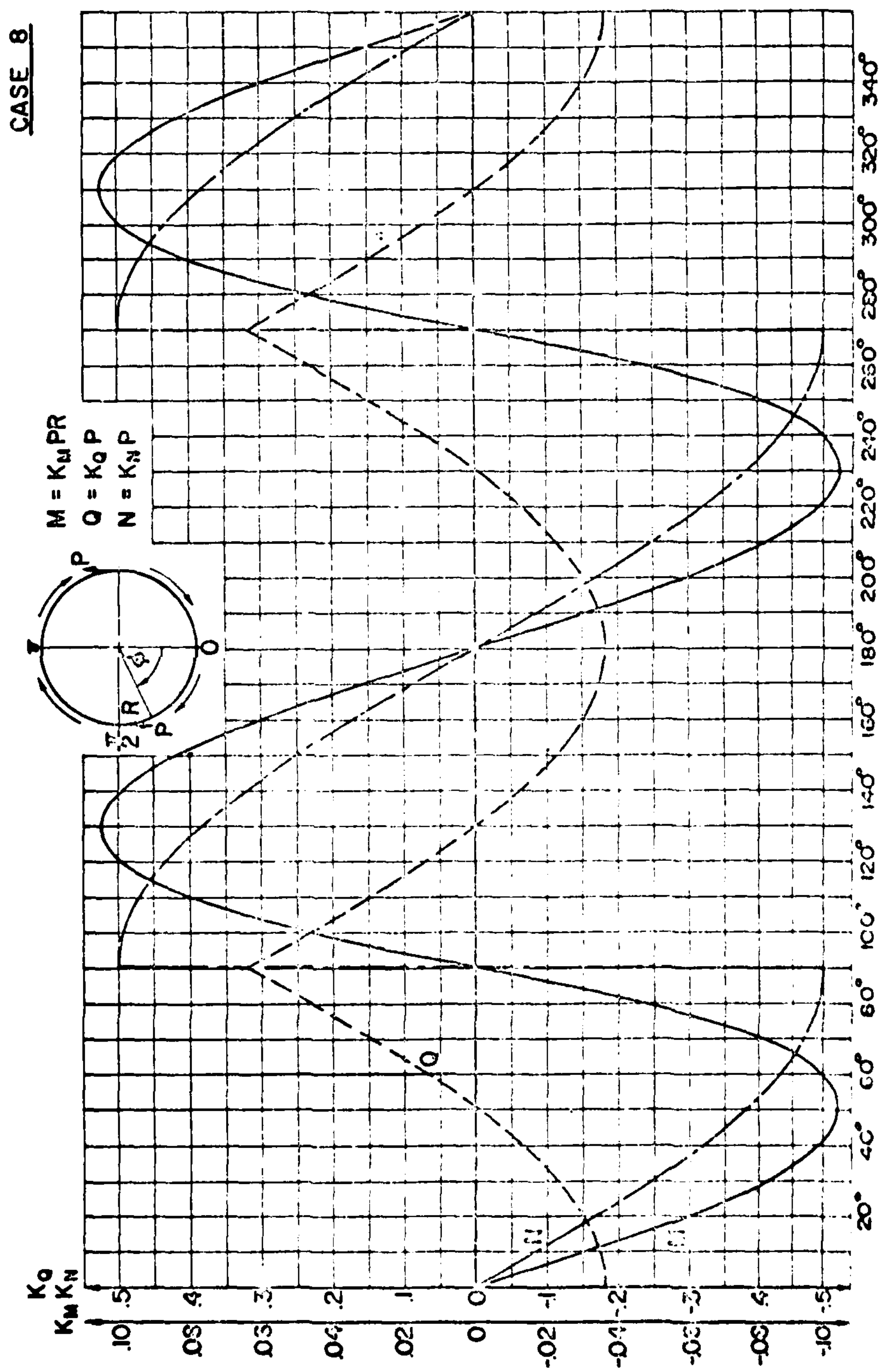
$$\tau_x = \frac{V_{MAX}}{H_{e\,90°}} = \frac{3{,}297}{2.45} = 1346 \text{ PSI}$$

COMBINED SHEAR (ASSUMING BOTH SHEAR STRESSES IS AT THE SAME POINT)

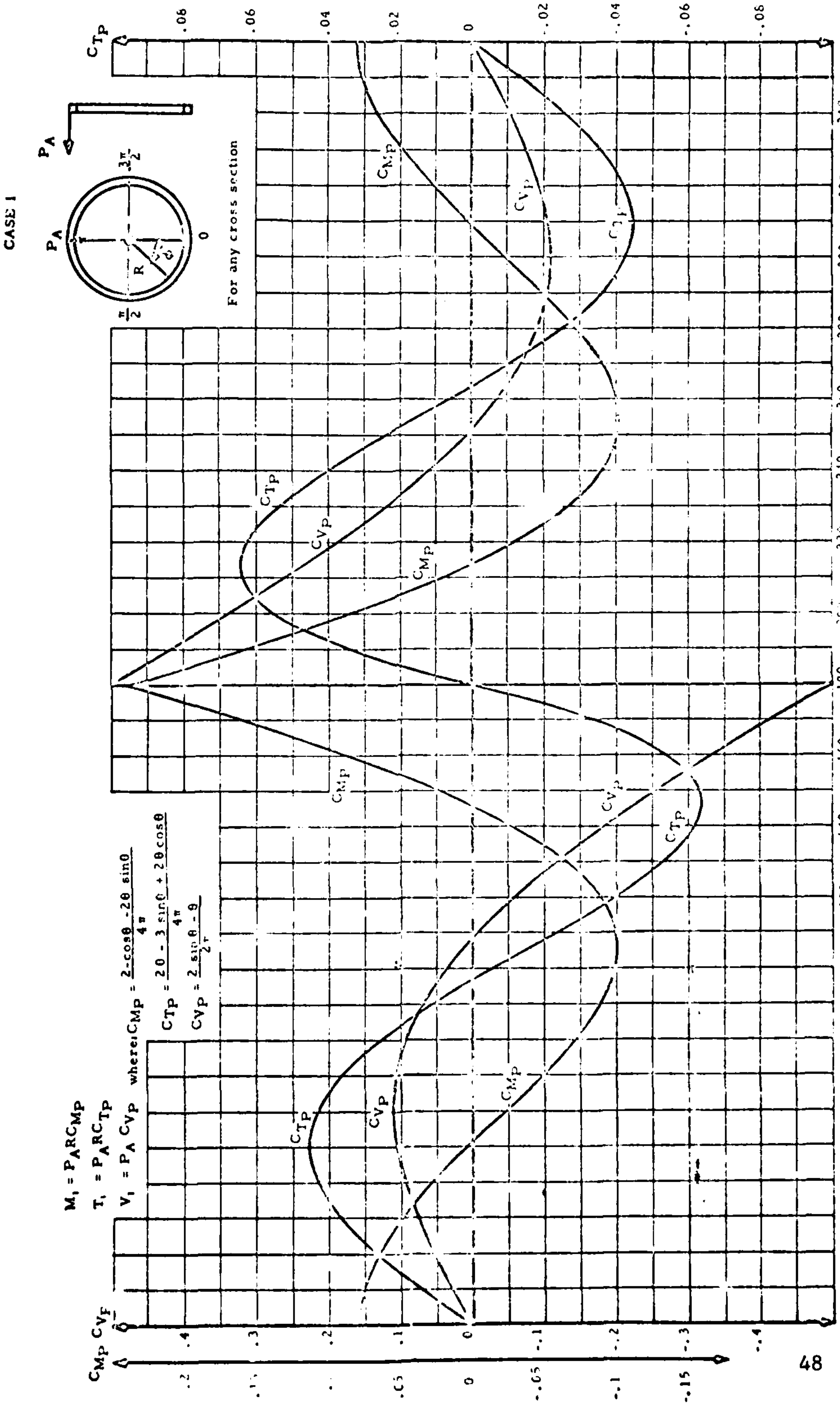
$$T_{xz} = \left[(1346)^2 + (1605)^2\right]^{1/2} = 2{,}092 \text{ PSI}$$

$$M.S. = \frac{4750}{2092} - 1 = +1.271$$

B 6.1.1 In-Plane Load Cases (Cont'd)



B 6.1.2 Out-of-Plane Load Cases (Cont'd)



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SKETCH NO. II-18

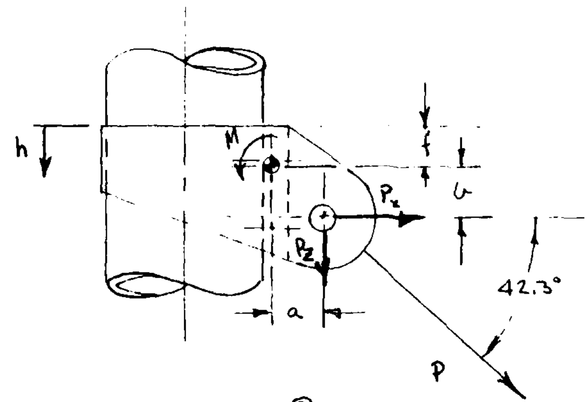
PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37B Landing Gear - Torque Arm Attachment

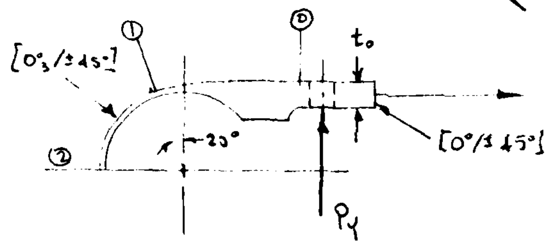
Torque Arm Attachment
Stresses in Band

Ult. Allowables for $[0^\circ_3/\pm 45^\circ]$ Lay-Up

$\sigma_x = 72{,}000$ psi $\sigma_y = 12{,}000$ psi
$\tau_{xy} = 20{,}000$ Interlaminar Shear $= 12{,}000$ psi



$h_{\oplus} = 3.28$ in.		$P = F = 13{,}931$ #
$h_1 = 2.21$ in		$P_x = 10{,}303$ #
$h_2 = 1.75$ in.		$P_z = 9{,}375$ #
$a = 1.250$ in		$P_y = 9{,}776$ #
$b = 1.138$ in		$t_o = .609$
$f = 1.112$ in.		$h_o = 3.35$ in
		$t_1 = t_2 = .210$ in.

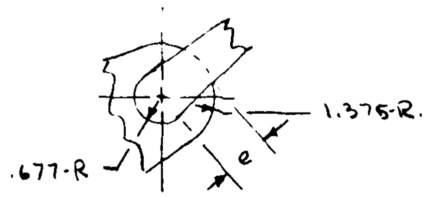


Shear Stress at (0) due to P_y

$$e = \left[(1.375)^2 - (.677)^2\right] = 1.197 \text{ in}$$

$$\tau_y = \frac{P_y}{\pi r + 2e} = \frac{9776}{\pi(.677) + 2 \times 1.197}$$

$$\tau_y = 2{,}162 \text{ psi}$$



Ultimate Allowables for $[0^\circ/\pm 45^\circ]$ $\phi = 6^\circ$

$\sigma_x = 52{,}000$ psi $\sigma_y = 14{,}000$ psi
$\tau_{xy} = 20{,}000$ psi
Interlaminar Shear $= 12{,}000$ psi

Shear Stresses at (0) due to P_z

$$\tau_z = \frac{P_z}{h_o t} = \frac{9375}{3.35 \times .609} = 4{,}595 \text{ psi}$$

Combining Both Shear Stresses at (0) – (τ_y & τ_z)

$$\tau_{yz} = \sqrt{\tau_y^2 + \tau_z^2} = \left[(2{,}162)^2 + (4{,}595)^2\right]^{1/2}$$

$$\tau_{yz} = 5{,}075 \text{ psi}$$

$$M.S. = \frac{20{,}000}{5{,}075} - 1 = +2.941$$

II-19

[illegible] (77°F)
[illegible]
[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	0°/±45°	[illegible]
[illegible]	8.45	[illegible]	11.5[illegible]	7.15	14.38
[illegible]	5.52	2.45	[illegible]	3.01	1.66
[illegible]	0.30	[illegible]	[illegible]	0.11	0.53
[illegible] $\times 10^6$	2.1[illegible]	2.[illegible]	1.[illegible]	[illegible]	1.26

[illegible]
[illegible]

[illegible] in/in/°F $\times 10^{-6}$	+0.369	[illegible]0.345	[illegible]0.352	− 0.2[illegible]	− 0.[illegible]
[illegible] in/in/°F $\times 10^{-6}$	+ 1.2[illegible]	+4.116	+ [illegible]	+ 2.471	+ [illegible]

[illegible]
[illegible]

[illegible], psi $\times 10^3$	[illegible]	[illegible]	[illegible]	41,[illegible]	[illegible]
[illegible], psi $\times 10^3$	58,400	[illegible]	[illegible]	4[illegible]	[illegible]3,[illegible]
[illegible], psi $\times 10^3$	37,950	[illegible]	15,[illegible]	[illegible]	11,4[illegible]
[illegible], psi $\times 10^3$	37,550	21,3[illegible]	20,0[illegible]	23,170	15,[illegible]
[illegible], psi $\times 10^3$	21,0[illegible]	21,0[illegible]	1[illegible]	30,[illegible]	12,580

DESIGN PROPERTIES (77°F)
FOR
AS/2002 GRAPHITE/ .688 % DET. RESIN [0°/±45°]
60 % FIBER VOL.
QUASI - ORTHOTROPIC

ELASTIC CONSTANTS

$E_x = 7.15 \times 10^6$ PSI

$E_y = 3.01 \times 10^6$ PSI

$\mu_x = 0.71$

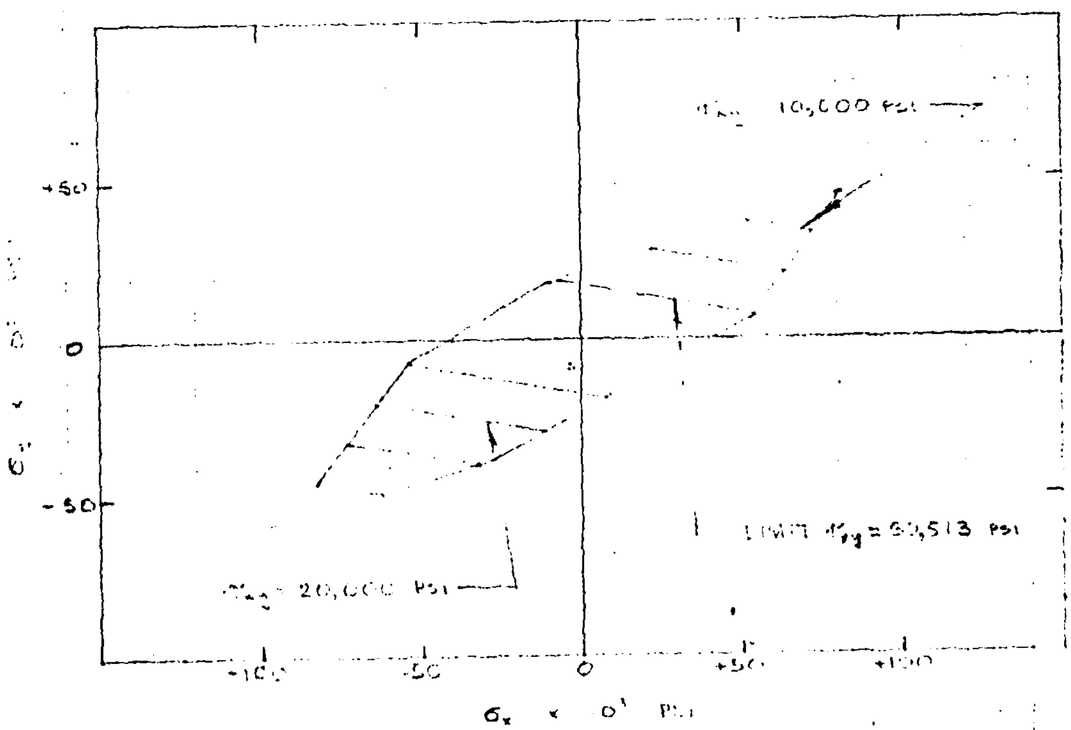
$G_{xy} = 3.08 \times 10^6$ PSI

THERMAL COEFFICIENTS

$\alpha_x = 0.224$ in/in/°F $\times 10^{-6}$

$\alpha_y = +2.471$ in/in/°F $\times 10^{-6}$

"LIMIT" INTERACTION CURVE



LRT

LAMINATE PROPERTIES (70°F)
FOR
AS/2002 GRAPHITE/.68 % UNIL PRESIN [0°₃/±45°]
60 % FIBER VOL.
QUASI - ORTHOTROPIC

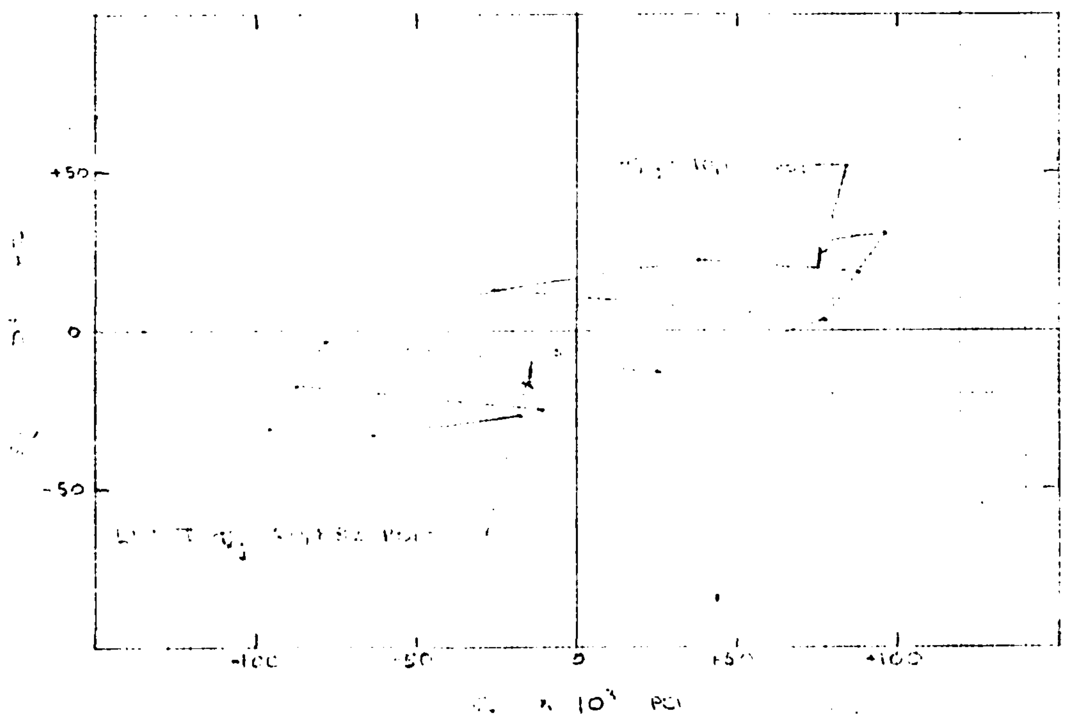
ELASTIC CONSTANTS

E_x	=	[illegible] $\times 10^6$	PSI
E_y	=	2.45×10^6	PSI
μ_x	=	[illegible]	
G_{xy}	=	[illegible] $\times 10^6$	PSI

THERMAL COEFFICIENTS

α_x	=	-0.345 IN/IN/°F $\times 10^{-6}$
α_y	=	$+4.116$ IN/IN [illegible]

[illegible] INTERACTION CURVE



DESIGN PROPERTIES (77°F)
FOR
2002 AS ($\epsilon_{11} = \epsilon_{22} = .65\%$) / 60% GRAPHITE FIBER VOL.
[0°/±45°] WITH $\phi = \pm 6°$
QUASI - ORTHOTROPIC

ELASTIC CONSTANTS

$E_x = 7.23 \times 10^6$ PSI $\quad \nu_{xy} = 0.29[illegible]$

$E_y = 3.07 \times 10^6$ PSI $\quad G_{xy} = 2.95 \times 10^{[illegible]}$ PSI

THERMAL COEFFICIENTS

$\alpha_x = -0.155$ IN/IN/°F $\times 10^{-6}$ $\quad \alpha_y = +2.441$ IN/IN/°F $\times 10^{-6}$

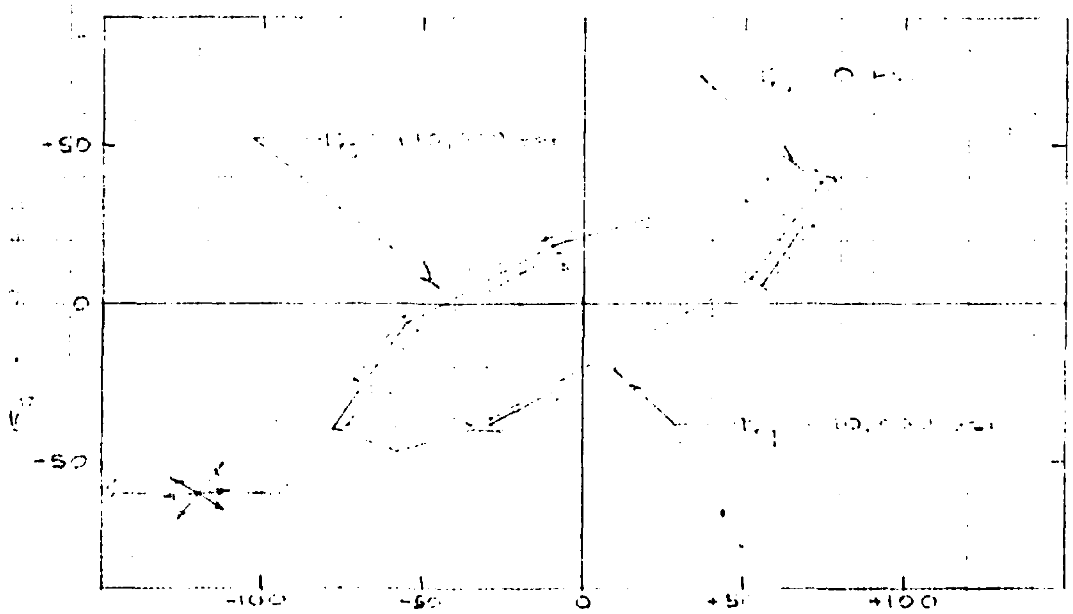
LIMIT STRENGTH

$\sigma_{xt} = 43,[illegible]$ PSI $\quad \sigma_{yt} = 21,030$ PSI

$\sigma_{xc} = 43,[illegible]$ PSI $\quad \sigma_{yc} = 23,570$ PSI

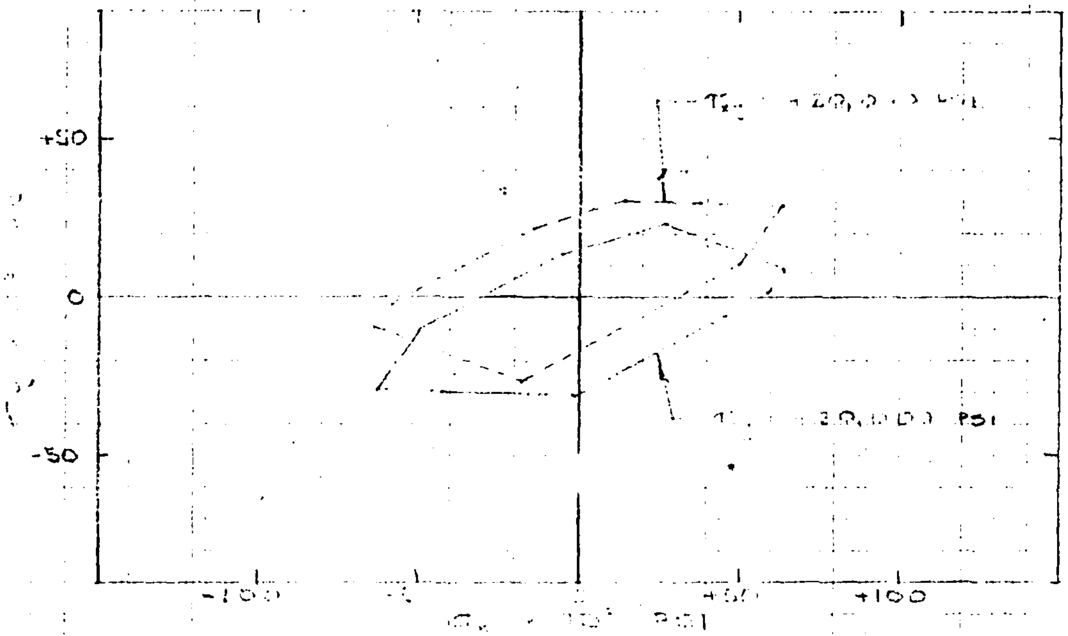
$\tau_{xy} = 21,5[illegible]$ PSI

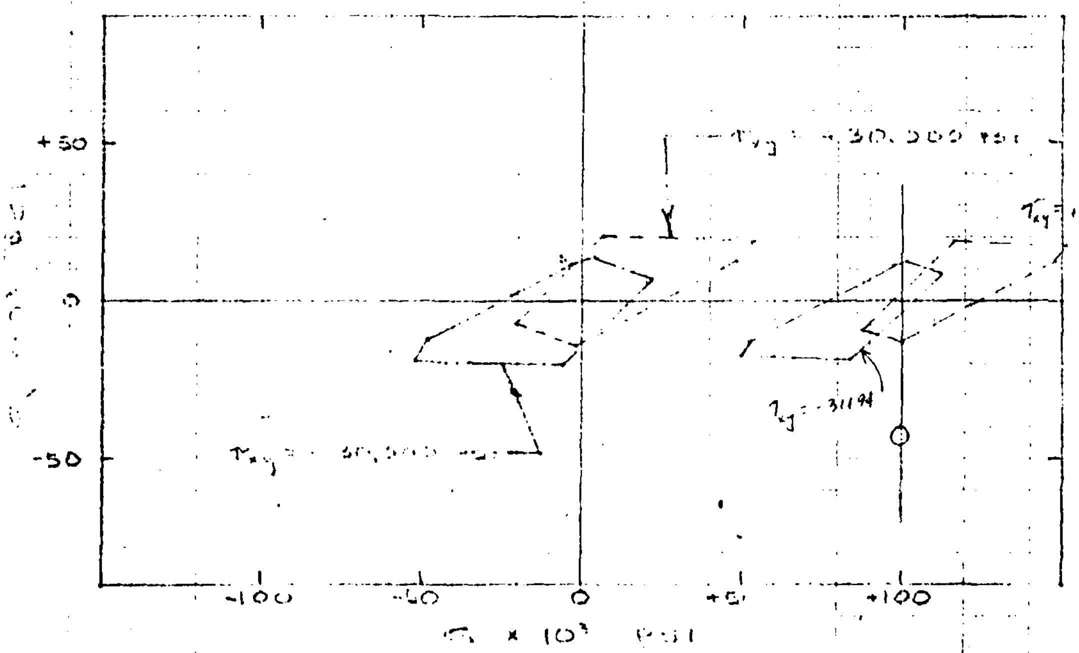
I[illegible] C[illegible]



2002 AS (ϵ_1 = ϵ_{2i} = .69 %) / 60 % GRAPHITE FIBER VOL.
[0°/±45°] WITH ϕ = 16°
(SHEET 2)

INTERACTION CURVES





LR
2-7-72

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SKETCH NO. II-24

PLANT ____ PROJECT NO. ____ DATE 2-73 AUTHOR E.R.T.

BLDG. ____ TITLE A-37B Landing Gear - Torque Arm Attachment

TORQUE ARM ATTACHMENT

STRESSES IN BAND

STRESSES AT (0) DUE TO P_x & P_z

$a_o = .93$ in; $b_o = .84''$; $t_o = .609''$; $h_o = 3.35$ in.

$$\sigma_t = \frac{P_x}{t_o \times h_o} = \frac{10,303}{.609 \times 3.35} = 5,050 \text{ psi}$$

$$I_o = \frac{t_o h_o^3}{12} = \frac{.609(3.35)^3}{12} = 1.90796 \text{ in}^4$$

$$c_o = h_o - f_o = 3.35 - 1.30 = 2.05 \text{ in.}$$

$$M_o = -b_o \times P_x + P_z \times a_o = -.84 \times 10,303 + .93 \times 9375 = +64.23 \text{ in-lbs}$$

$$\sigma_{bt_o} = \frac{M_o c_o}{I_o} = \frac{64.23 \times 2.05}{1.908} = 69.0 \text{ psi}$$

COMBINING BOTH STRESSES AT (0)

$$\sigma_{t_o} = \sigma_t + \sigma_{bt_o} = 5,050 + 69 = 5,119 \text{ psi}$$

$$M.S. = \frac{52,000}{5,119} - 1 = +9.174$$

STRESSES AT (1) DUE TO P_x & P_z

$$M_1 = -P_x \times b + P_z \times a = -10,303 \times 1.138 + 9375 \times 1.250 =$$
$$M_1 = -6.1 \text{ in-lbs}$$

$$I_1 = \frac{.210(2.21)^3}{12} = .18880 \text{ in}^4$$

$$c_1 = \frac{h_1}{2} = \frac{2.21}{2} = 1.105 \text{ in}$$

BENDING STRESSES AT (1)

$$\sigma_{b_1} = \frac{Mc}{I} = \frac{6.1 \times 1.105}{.19} = \mp 35.5 \text{ psi}$$

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SKETCH NO. II-25

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR E. RT

BLDG. ______ TITLE A-37B Landing Gear - Torque Arm Attachment

TORQUE ARM ATTACHMENT

STRESSES AT BAND

STRESSES AT (1)

TENSILE STRESSES AT (1)

$$\sigma_{t_1} = \frac{P_x}{t_1 \times h_1} = \frac{10,303}{.210 \times 2.21} = +22,200 \text{ PSI}$$

BENDING STRESSES DUE ECCENTRICITY AT (1)

$$\sigma_{be_1} = \frac{P_x \left(\frac{h_1}{2} - f\right) \times c_1}{I_1} = \frac{10,303 \left(\frac{2.21}{2} - 1.112\right) \times 1.105}{.1889}$$

$$\sigma_{be_1} = \mp 422.2 \text{ PSI}$$

TOTAL TENSILE STRESSES AT (1)

$$\sigma_{t t_1} = \sigma_{b_1} + \sigma_{t_1} + \sigma_{be_1} = 35.5 + 22,200 + 422.2$$

$$\sigma_{tt_1} = 22,658 \text{ PSI}$$

$$M.S. = \frac{72,000}{22,658} - 1 = +2.178$$

STRESSES AT (2)

$$\frac{I_2}{c} = \frac{.21 (1.75)^2}{6} = .10718 \text{ in}^3$$

BENDING AT (2)

$$\sigma_{b_2} = \frac{6.1}{.107} = \mp 57 \text{ PSI}$$

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SKETCH NO. II-26

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37B Landing Gear - Torque Arm Attachment

Torque Arm Attachment

Stresses at Band

Stresses at (2)

Tensile at (2)

$$\sigma_{t_2} = \frac{10,303}{.210 \times 1.75} = +28,035 \text{ PSI}$$

Eccentricity at (2)

$$\sigma_{be_2} = \frac{10,303\left(\frac{1.75}{2} - 1.112\right)}{.1072} = \mp 22,778 \text{ PSI}$$

Total Tensile Stresses at (2)

$$\sigma_{tt_2} = \sigma_{b_2} + \sigma_{t_2} + \sigma_{be_2} = \mp 57 + 28,035 \mp 22,778$$

$$\sigma_{tt_2} = +50,870 \text{ PSI}$$

$$M.S. = \frac{72,000}{50,870} - 1 = +.415$$

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HERCULES INCORPORATED
ENGINEERING DEPARTMENT

SKETCH NO. II - 27

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR ERT

BLDG. ______ TITLE A-37B Landing Gear - Torque Arm Attachmt

Torque Arm Attachment

Summary of Margins of Safety

Lug Loads

Tension
- Bearing M.S. = +.801
- Tensile M.S. = +1.656
- Tear-Out Shear +1.523

Compression
- Bearing +1.017
- Compression +1.973
- Interlaminar Shear +1.195

Band Loads

Bonding to Tube (Shear) +1.271

Stresses at (0)
- Shear +2.941
- Tension +9.174

Stresses at (1)
- Tension +2.178

Stresses at (2)
- Tension + .415

APPENDIX A
PART III

DESIGN ANALYSIS
OF
THE OUTER CYLINDER/TRUNNION

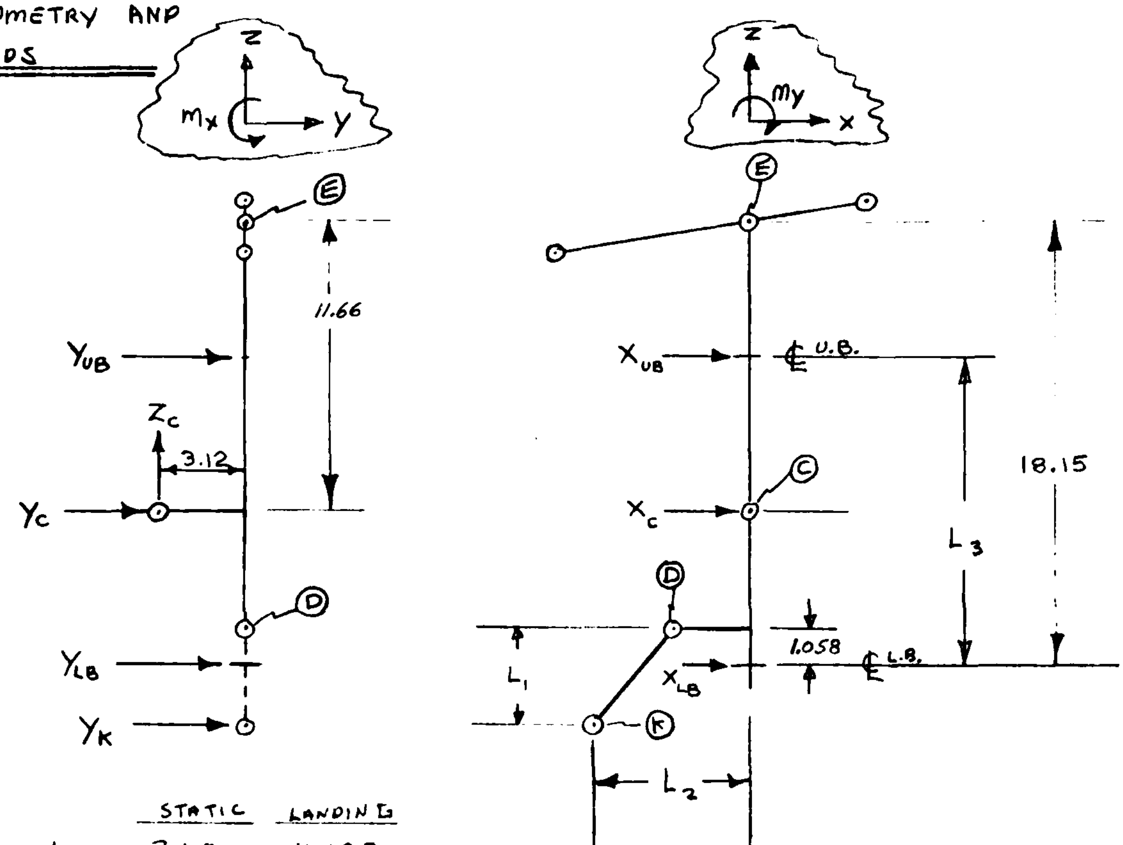
HERCULES INCORPORATED
ENGINEERING DEPARTMENT

SKETCH NO. III-1

PLANT Bacchus PROJECT NO. DATE AUTHOR JnB

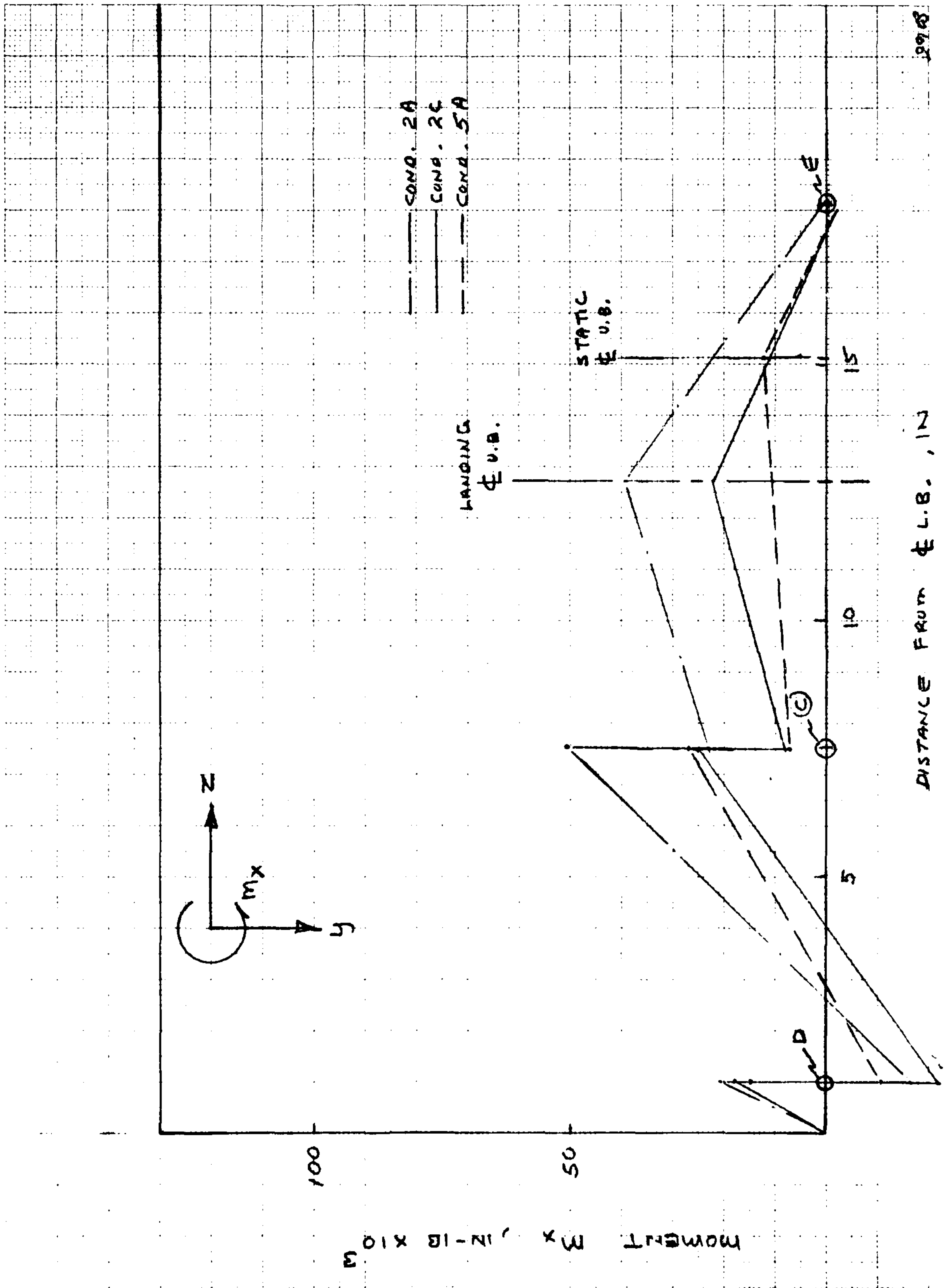
BLDG. TITLE A-37B LANDING GEAR

OUTER CYLINDER
GEOMETRY AND
LOADS

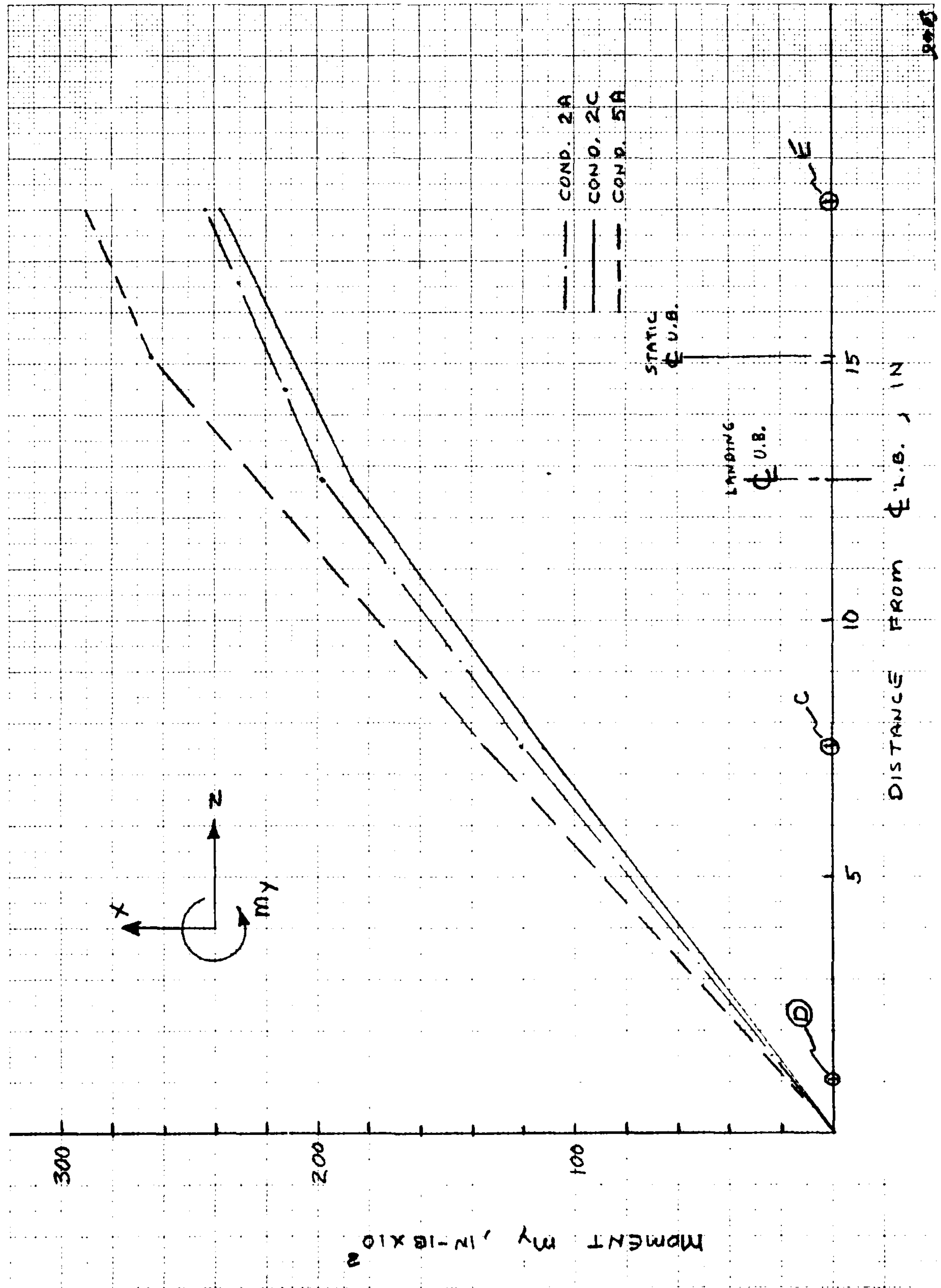


	STATIC	LANDING
L_1	3.118	4.128
L_2	8.000	8.740
L_3	15.120	12.720

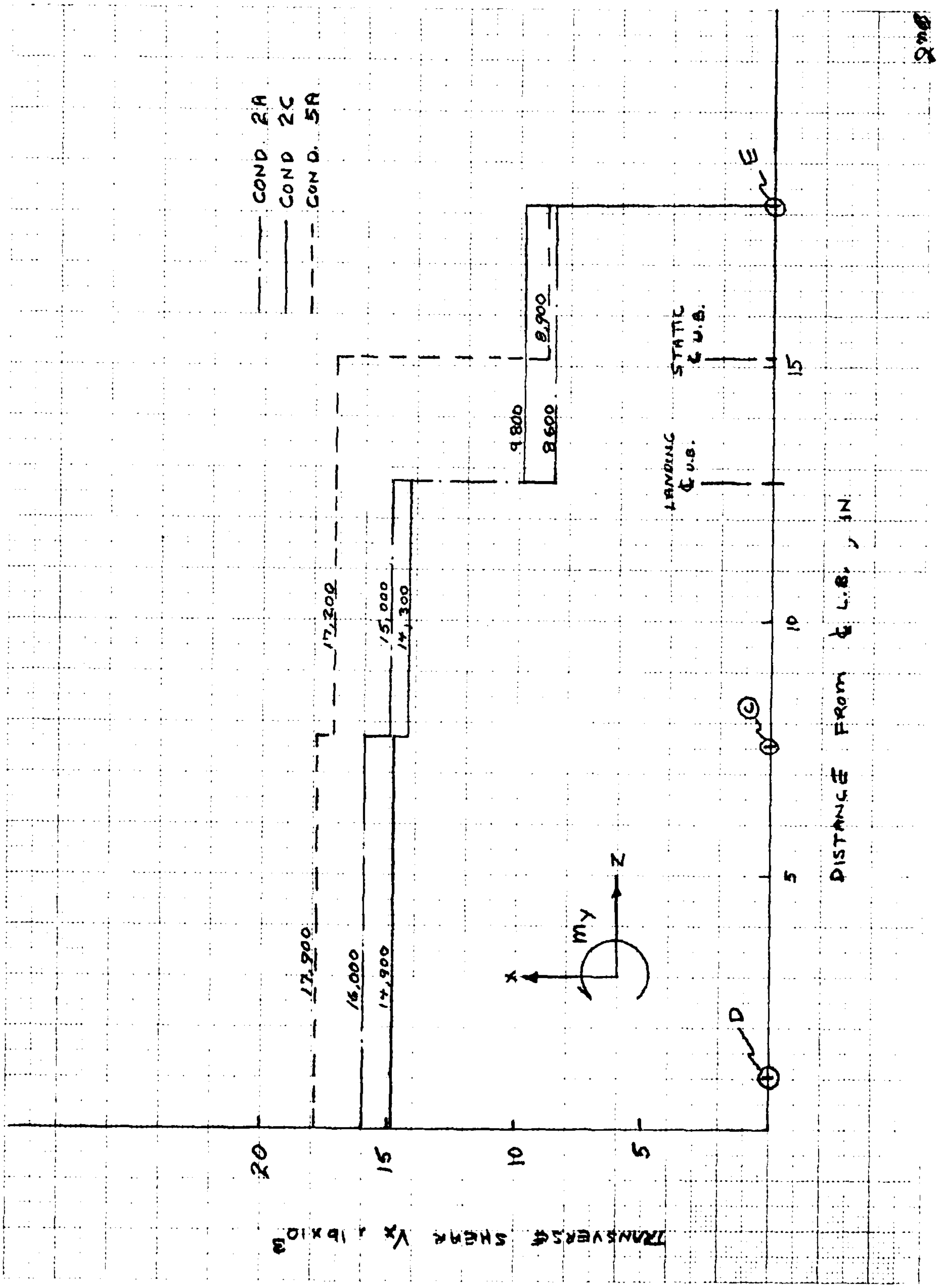
Load Condition			X_{LB}	Y_{LB}	Y_K	X_C	Z_C	Y_C	$X_{U.B}$	$Y_{U.B}$
2 Pt. Level Landing	Max. Vert.	1A	-9500	-15300	5200	1100	-9300	7500	3900	10100
	Spin-up	1B	12100	3900	-6800	500	-4100	3300	-4800	2900
	Spring Back	1C	-16200	-18200	9100	900	-7600	6200	6400	9100
Tail Down Landing	Max. Vert.	2A	-16000	-19400	9000	1000	-8900	+7230	6400	10400
	Spring Back	2C	-14900	-17000	9700	600	-5600	4600	4500	7200
Drift Landing	Right	3A	-1400	6100	300	-1000	9000	-7300	500	-1800
	Left	3B	-1400	-21000	1600	2600	-22600	18300	500	13300
Braked Roll		4A	14700	1300	-6100	700	-6300	5100	-7500	4800
Reverse Brake		5A	-17900	-14000	8200	700	-6300	5100	8300	5800
Right Turn		6A	-1800	-19100	1700	2600	-22700	18400	500	11600

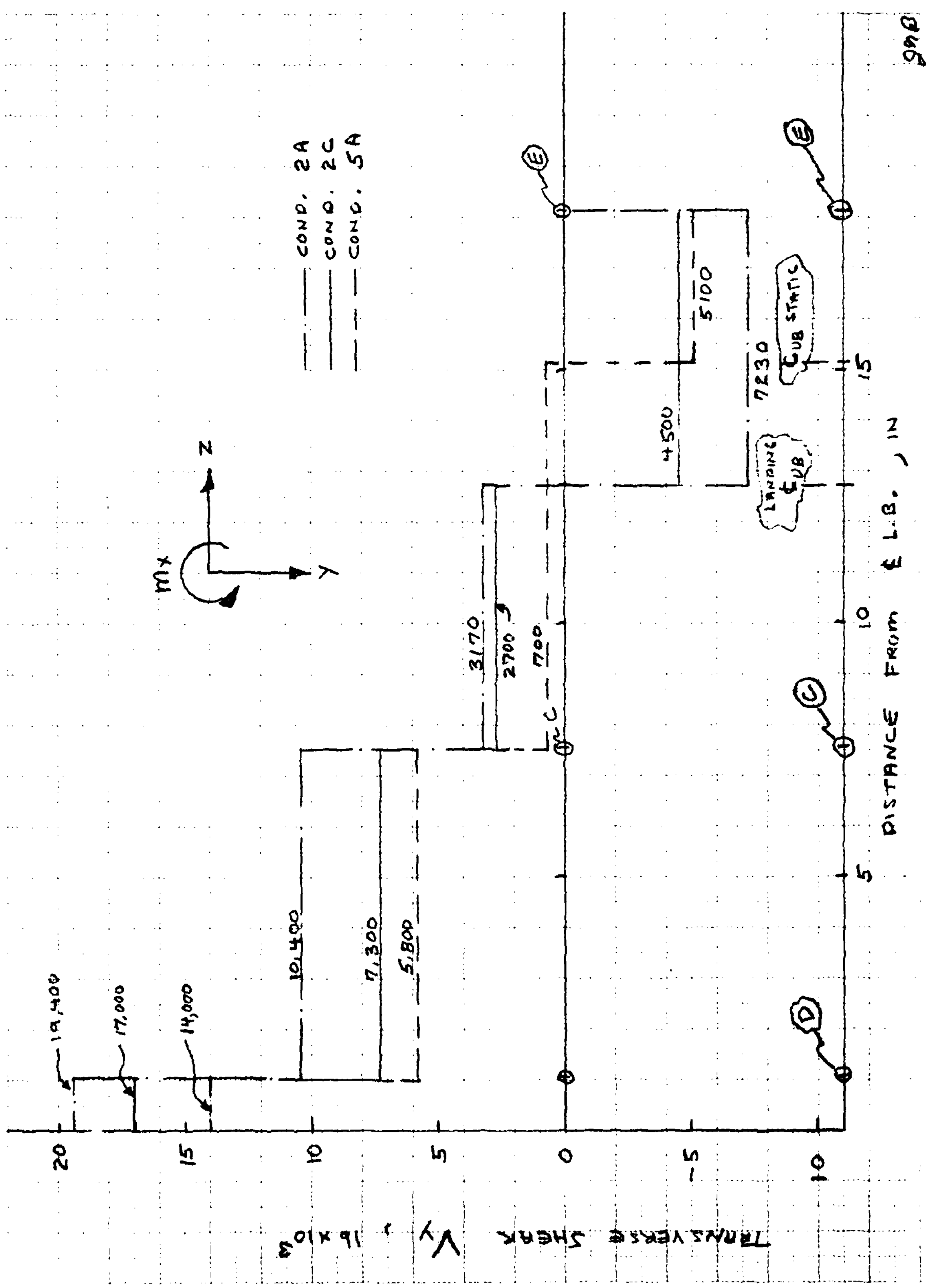


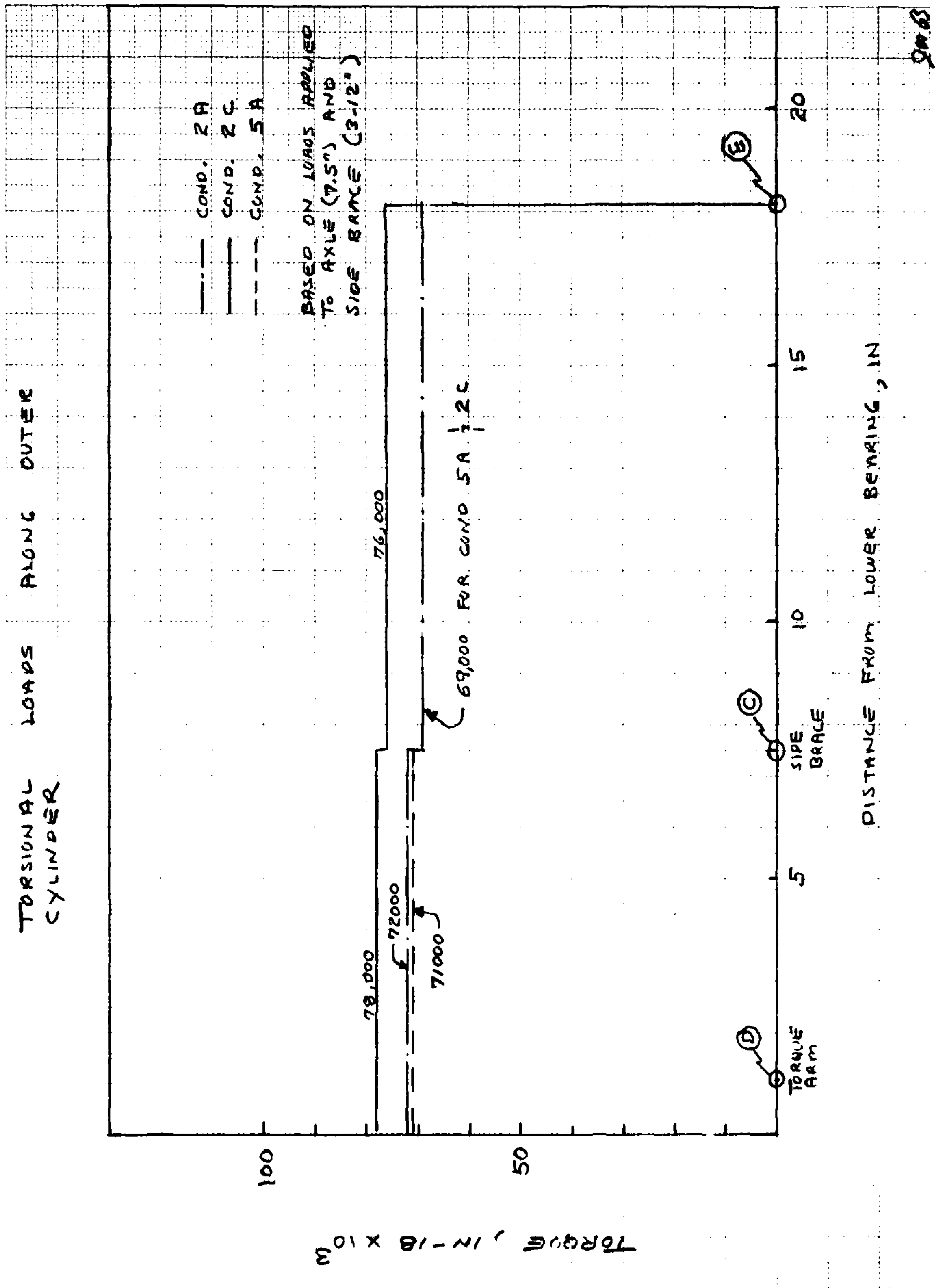
COND. 2A
COND. 2C
COND. 5A
STATIC
℄ U.B.
LANDING
℄ U.B.
E
C
D
N
m_x
y
15
10
5
DISTANCE FROM ℄ L.B., IN
100
50
MOMENT M_x, IN-LB x10^3



MOMENT my, IN-LB x10^2
300
200
100
DISTANCE FROM ℄ L.B., IN
5
10
15
COND. 2A
COND. 2C
COND. 5A
STATIC ℄ U.B.
LANDING ℄ U.B.
C
D
E
X
Z
my


COND 2A
COND 2C
COND. 5A
17,900
16,000
14,900
17,200
15,000
14,300
9800
8600
8,900
STATIC ℄ U.B.
LANDING ℄ U.B.
DISTANCE FROM ℄ L.B., IN.
TRANSVERSE SHEAR Vx, lb x 10³
My
X
Z
D
E
C
5
10
15
20


TRANSVERSE SHEAR Vy, lb x10³
DISTANCE FROM ℄ L.B., IN
COND. 2A
COND. 2C
COND. 5A
Mx
Z
Y
19,400
17,000
14,000
10,400
7,300
5,800
3170
2700
700
4500
5100
7230
LANDING ℄ UB
℄ UB STATIC
C
D
E
20
15
10
5
0
-5
-10
99B


TORSIONAL LOADS ALONG OUTER CYLINDER
COND. 2A
COND. 2C
COND. 5A
BASED ON LOADS APPLIED TO AXLE (7.5") AND SIDE BRACE (3.12")
76,000
69,000 FOR COND 5A & 2C
78,000
72000
71000
D
TORQUE ARM
C
SIDE BRACE
E
0
5
10
15
20
DISTANCE FROM LOWER BEARING, IN
100
50
TORQUE, IN-LB x 10^3

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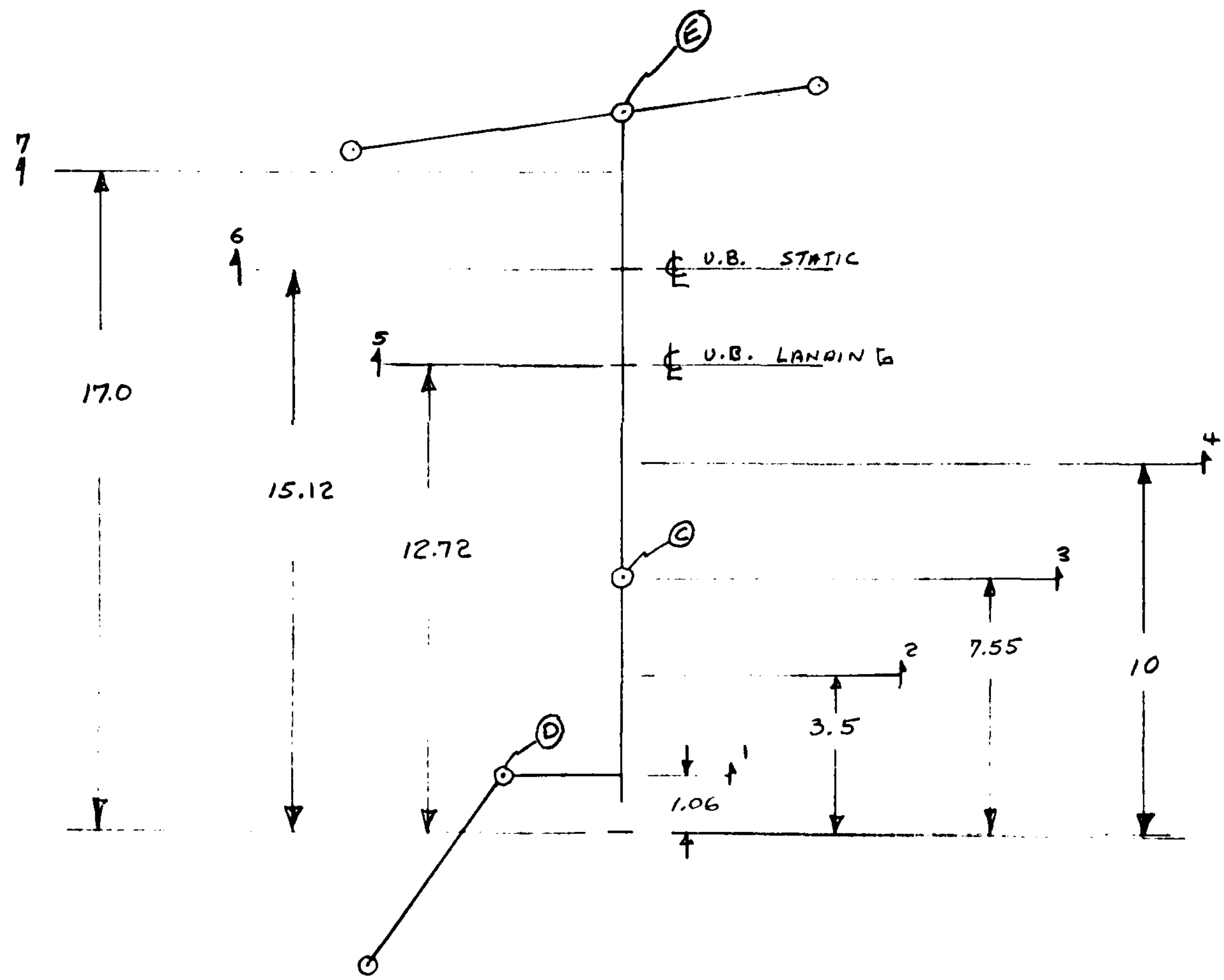
III-7

SKETCH NO.

PLANT PROJECT NO. DATE 2-73 AUTHOR J.M.B.

BLDG. TITLE A-37 B LANDING GEAR

OUTER CYLINDER
ANALYSIS LOCATIONS



TABLE

ULTIMATE LOADS[1] USED TO DESIGN THE OUTER CYLINDER/TRUNNION

Location[2]	F_2	M_x	M_y	M_{ecs}	V_x	V_y	V_{res}	τ
1	0	22,000	16,000	27,200	17,900	10,400	20,700	78,000
2	0	9,000	62,000	62.700	17,900	10,400	20,700	78,000
3	-8900	51,000	135,000	144,000	17,900	10,400	20,700	78,000
4	-8900	31,000	176,000	178,500	17,200	3,170	17,500	76,000
5	-8900	39,000	223,000	226,500	17,200	7,230	18,650	76.000
6	-8900	22,000	264,000	265,000	17,200	7,230	18,650	76,000
7	-8900	9,000	281,000	281,000	9,800	7,230	12,150	76,000

(1) Maximum values from ~~Figures~~ p. III-2 through ~~4~~ p. III-6 regardless of load condition; all load conditions lumped together. This will provide a slightly conservative analysis.

(2) SEE PAGE III-7

OUTER CYLINDER/TRUNNION
LOADS AT ATTACHMENT
TO A-37 B AIRCRAFT

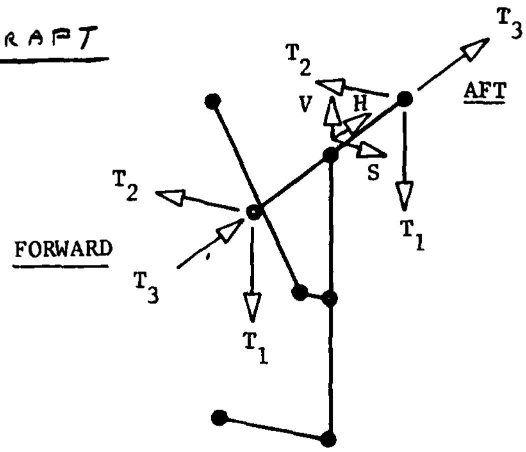


Figure IV.16. Trunnion Reaction Loads in H,S,V System

TABLE IV.17

TRUNNION REACTION LOADS IN H,S,V SYSTEM FOR BALL JOINTS

	Forward			Aft		
Case	T_1 Lbs	T_2 Lbs	T_3 Lbs	T_1 Lbs	T_2 Lbs	T_3 Lbs
1A	13,066	5970	3866	-6,958	1547	0
1B	-14,404	-2965	0	17,088	6267	-8124
1C	21,255	7816	8313	-16,254	-1661	0
2A	21,259	8146	7965	-15,403	-938	0
2C	22,379	7630	9393	-18,675	-3071	0
3A	-6,308	5066	17	-8,418	6657	0
3B	9,354	-495	26	7,135	-1771	0
4A	-17,884	-2251	0	22,017	7338	-8444
5A	24,253	7309	8363	-20,120	-2222	0
6A	-4,196	5432	-14	-6,732	6709	0
7	1,851	3394	-2173	5,648	5836	0

NOTE: LOADS APPLY AT CENTER OF AIRCRAFT ATTACHMENT BUSHING.

OUTER CYLINDER / TRUNNION
LOADS AT ATTACHMENT
TO A 37 B AIRCRAFT

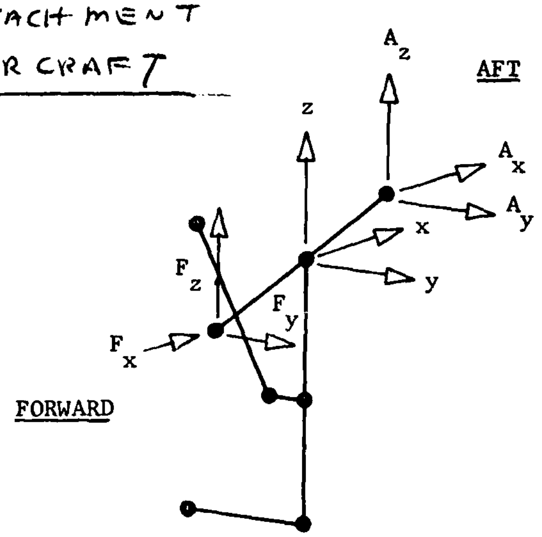


Figure IV.18. Trunnion Reaction Loads

TABLE IV.19

TRUNNION REACTION LOADS IN THE x,y,z SYSTEM FOR BALL JOINTS

Cond	F_x Lbs	F_y Lbs	F_z Lbs	A_x Lbs	A_y Lbs	A_z Lbs
1A	5,320	-5,970	-12,544	-787	-1,547	6,913
1B	-1,630	2,965	14,311	-6,137	-6,267	-17,897
1C	10,665	-7,816	-20,177	-1,840	16,612	16,149
2A	10,320	-8,146	-20,217	-1,743	938	15,303
2C	11,865	-7,630	-21,171	-2,114	3,071	18,553
3A	-697	-5,066	6,269	-953	-6,657	8,363
3B	1,084	495	-9,290	807	1,771	-7,089
4A	-2,024	2,251	17,769	-5,897	-7,338	-22,831
5A	11,054	-7,309	-23,150	-2,277	2,222	19,990
6A	-488	-5,432	4,167	-762	-6,709	6,688
7	-1,949	-3,394	-2,085	639	-5,836	-5,611

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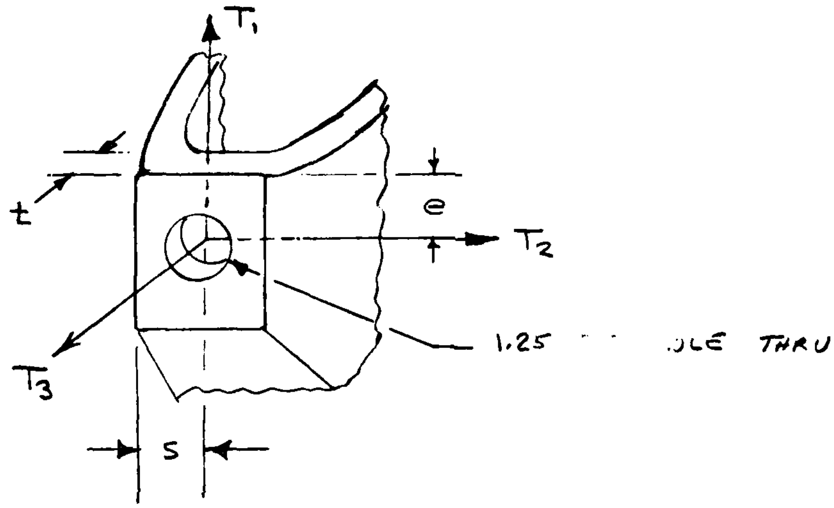
SKETCH NO. III-11

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTH. MB

BLDG. ______ TITLE A-37B LANDING GEAR

OUTER CYL. / TRUNNION
GEAR / AIRCRAFT
ATTACHMENT LUGS, AFT.



LOADS

LOAD	COND. 4A ①	COND. 5A ②
T_1	27,323	-24,969
T_2	-9,106	2,755
T_3	-8,444	0

$$F_{max} = \sqrt{T_1^2 + T_2^2} = \sqrt{(27,323)^2 + (-9106)^2}$$

$$= 28,800\ \#$$

① VALUES ARE LARGER THAN SHOWN IN LOADS TABLE BECAUSE THEY APPLY AT THE TRUNNION BUSHING RATHER THAN AT THE AIRCRAFT BUSHING.

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BEARING ALLOWABLES (SEE CURVE ON NEXT PAGE)

e/D	F_{BR}	① 50% F_{BR}
2.5	135,000	67,500
2.0	125,000	62,500
1.5	100,000	50,000
4.0	155,000	77,500

SHEAR ALLOWABLES

$$\tau_{ALL} = \frac{F_{BR}}{2(e/D - .5)}$$

e/D	50% F_{BR}	τ_{ALL}
2.5	67,500	16,900
2.0	62,500	20,800
1.5	50,000	25,000
4.0	77,500	11,000

TENSILE ALLOWABLES

$$F_{ALL} = \frac{F_{BR}}{2(S/D - .5)}$$

S/D	50% F_{BR}	F_{ALL}
4.0	77,500	11,000
2.5	67,500	16,900
2.0	62,500	20,800
1.5	50,000	25,000

① REDUCED BY 50% TO ACCOUNT FOR FATIGUE AND UNCERTAINIES IN F_{BR} VALUES.

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BLDG. ______ TITLE A-37 B LANDING GEAR

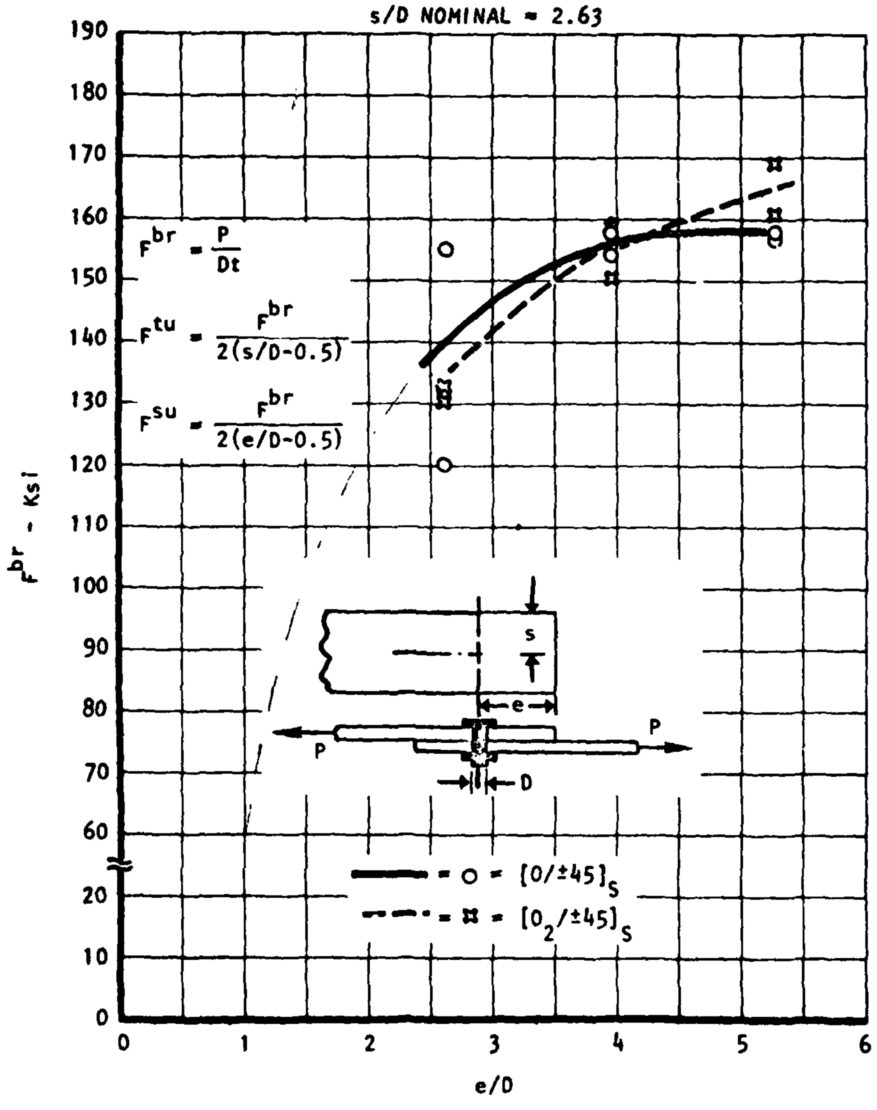

Figure 140. Graphite/Epoxy to Steel Mechanical Joint Single Lap Bearing Strength Versus e/D at Room Temperature (Type AS/3002, Batch) Protruding Head Fastener

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SKETCH NO. III-14

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BLDG. ______ TITLE A-37B LANDING GEAR

t REQ FOR BEARING

$$\sigma_B = \frac{F}{Dt} = \frac{28,800}{1.25t} = \frac{23,000}{t}$$

$$t = \frac{23,000}{F_{BR}}$$

e/D	F_{BR}	t
4.0	77,500	.297
2.5	67,500	.340
2.0	62,500	.368
1.5	50,000	.460

SELECTED DESIGN

t REQ FOR SHEAR

$$\tau = \frac{F}{A_s} = \frac{F}{2et} \qquad t = \frac{F}{2e\tau_{ALL}}$$

$$t = \frac{28,800}{2e\tau_{ALL}} = \frac{14,400}{e\tau_{ALL}}$$

e/D	D	e	τ_{ALL}	t
4.0	1.25	5.00	11,000	.262
2.5		3.13	16,900	.273
2.0		2.50	20,900	.28[illegible]
1.5		1.88	25,000	.307

SELECTED DESIGN

t REQ FOR TENSION

$$\sigma_T = F/A = F/(2S-D)t = 28,800/(2S-1.25)\,t$$

S/D	σ_{ALL}	S	2S-1.25	t
4.0	11,000	5.0	8.75	.299
2.5	16,900	3.13	5.01	.340
2.0	20,900	2.50	3.75	.37
1.5	25,000	1.88	2.51	.46

SELECTED DESIGN

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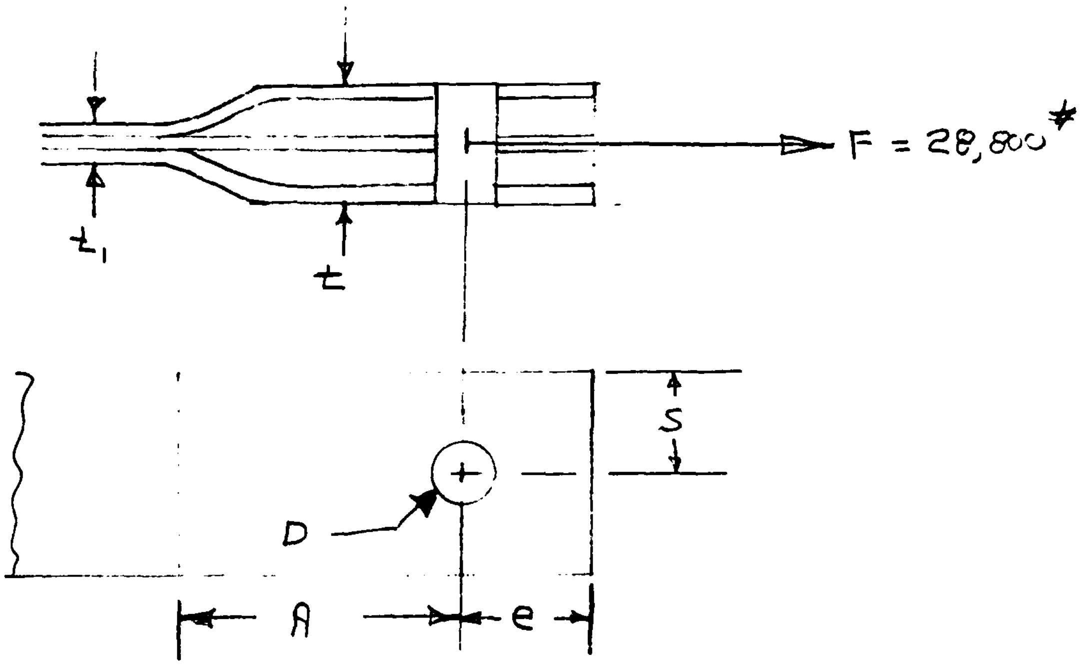
SKETCH NO. III-15

PLANT ________ PROJECT NO. ________ DATE 2-73 AUTHOR gmB

BLDG. ________ TITLE A-37B LANDING GEAR

REQ. LENGTH OF REINFORCEMENT (TRUNNION LUGS)



$$\sigma_T \ @ \ t = \frac{F}{(2S-D)t} = \frac{28{,}800}{(2S-D)t} =$$

$$\tau = k\frac{F'}{A} = \frac{k}{2SA}\left(\frac{t-t_1}{t}\,\sigma_T\right) = \frac{2}{2SA}\left(\frac{t-t_1}{t}\times\sigma_T\right)$$

$$\tau = \frac{1}{SAt}\left[(t-t_1)\,\sigma_T\right]$$

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SKETCH NO. III-16

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BLDG. ______ TITLE A-37B LANDING GEAR

REQ LENGTH OF REINFORCEMENT (TRUNNION LUGS)

LET. $\tau_{ALLOWABLE} = 6{,}000$ PSI

$e/D = 2.0$ $\quad D = 1.25$, $e = 2.5$

$s/D = 2.0$ $\quad b = 1.25$, $s = 2.5$

$t = 0.4$

$$\sigma_T = \frac{28{,}800}{(2s - D)t} = \frac{28{,}800}{[(2)(2.5) - 1.25].4} = 19{,}200 \text{ PSI}$$

$$A_{req} = \frac{1}{s t \tau_{ALL}} \left[(t - t_1)\, \sigma_T \right] = \frac{1}{(2.5)(.4)(6000)} \left[(.4 - t_1)\, 19{,}200 \right]$$

$$A_{req} = 1.67 \times 10^{-4} \left[(.4 - t_1)\, 19{,}200 \right]$$

$$t_1 = \frac{14{,}400}{\sigma_{T_{ALLOW.}}\, s} = \frac{14{,}400}{(50{,}000)(2.5)} = .115$$

$$A_{req} = 1.67 \times 10^{-4} \left[(1.4 - .115)\, 19{,}200 \right]$$

$$= 1.67 \times 10^{-4} \left[5472 \right] = \underline{.91 \text{ IN}}$$

$$\boxed{\text{USE MIN. LENGTH} = 1.0 \text{ IN}}$$

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III – 17

SKETCH NO. ______

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR gmB

BLDG. ______ TITLE A-37 B LANDING GEAR

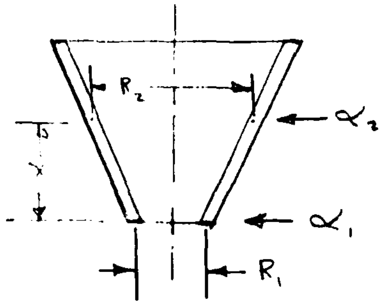
OUTER CYLINDER
WINDING PATTERN

ASSUMPTION

ELLIPSE PORTION OF OUTER CYLINDER WILL BE APPROXIMATED BY A CONE HAVING CIRCUMFERENTIAL DISTANCES EQUAL TO THE ELLIPSE CIRCUMFERENTIAL DISTANCES.

SECTION	ELLIPSE AREA @ t=.1	EQUIVALENT CONE DIA. = D ①	D/2 = R
3	1.054	3.36	1.68
4	1.139	3.62	1.81
5	1.594	5.08	2.54
6	2.018	6.43	3.22
7	2.176	6.95	3.47

CONE WINDING ANGLES AND THICKNESSES

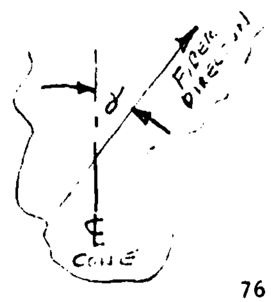


$$R_1 \sin\alpha_1 = R_2 \sin\alpha_2$$

$$\alpha_2 = \text{ARC-SIN}\left(\frac{R_1}{R_2}\sin\alpha_1\right)$$

$$t_2 R_2 \cos\alpha_2 = t_1 R_1 \cos\alpha_1$$

$$\frac{t_2}{t_1} = \frac{R_1 \cos\alpha_1}{R_2 \cos\alpha_2}$$



① $D = \frac{A}{\pi t} = \frac{A}{.3146}$

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BLDG. ____ TITLE ____

OUTER CYLINDER
WINDING PATTERN

cos 80 = .1736
[illegible] = .342
cos [illegible] = .423
cos 50° = .[illegible]
cos [illegible] = .5000

WINDING ANGLES

SECTION	R_1/R_2	α_2 FOR $\alpha_1 = 80$	$\alpha_1 = 70$	$\alpha_1 = 65$	$\alpha_1 = 60$	$\alpha_1 = 50$	[illegible]
3-3	1.0	80.0	70.	65.0	[illegible]	50.0	-
4-4	.928	66.1	60.[illegible]	57.2	[illegible]	45.[illegible]	[illegible]
5-5	.661	40.6	38.4	36.[illegible]	34.[illegible]	30.4	13.[illegible]
6-6	.522	30.9	29.4	[illegible]8.2	[illegible]	23.6	10.3
7-7	.484	28.5	27.1	[illegible]	24.5	21.8	9.5

WALL THICKNESSES

SECTION	t_2/t_1 FOR $\alpha_1 = 80$	$\alpha_1 = 70$	$\alpha_1 = 65$	$\alpha_1 = 60$	$\alpha_1 = 50$
3-3	1.0	1.0	1.0	1.0	1.0
4-4	.4	.65	.72	.78	.85
5-5	.15	[illegible]	.35	[illegible]	.49
6-6	.106	.20	.25	.29	.37
7-7	.10	.19	.23	.27	.34

TABLE

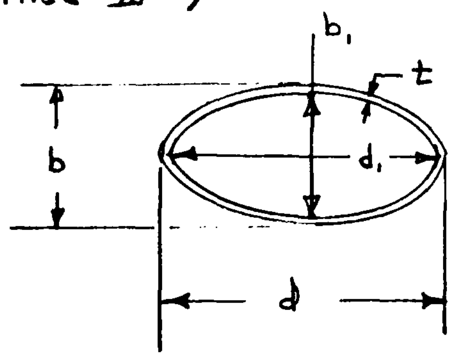
OUTER CYLINDER SECTION PROPERTIES

Section(3)	b_1	d_1	t = .1 $A^{(1)}$	t = .1 $I^{(2)}$	t = .2 $A^{(1)}$	t = .2 $I^{(2)}$	t = .3 $A^{(1)}$	t = .3 $I^{(2)}$	t = .4 $A^{(1)}$	t = .4 $I^{(2)}$
3-3	3.25	3.25	1.054	1.479	2.17	3.24	3.348	5.31	4.59	7.73
4-4	3.25	3.80	1.139	2.09	2.34	4.52	3.605	7.35	4.93	10.60
5-5	3.25	6.70	1.594	7.65	3.25	16.14	4.97	25.54	6.75	35.89
6-6	3.25	9.40	2.018	17.32	4.10	36.13	6.24	56.48	8.45	78.47
7-8	3.25	10.4	2.176	22.25	4.41	46.25	6.72	72.09	9.08	99.84

(1) $A = \frac{\pi}{4}(bd - b_1 d_1) = \frac{\pi}{4}\left[(b_1 + 2t)(d_1 + 2t) - b_1 d_1\right]$

(2) $I = \frac{\pi}{64}\left[bd^3 - b_1 d_1^3\right] = \frac{\pi}{64}\left[(b_1 + 2t)(d_1 + 2t)^3 - b_1 d_1^3\right]$

(3) See figure. PAGE III-7



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PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE A-37 B LANDING GEAR

OUTER CYLINDER
STRESSES DUE TO
8900# AXIAL LOAD
AT SECTION 3-3

$$\sigma_A = \frac{F}{A} = \frac{F}{\pi d t}$$

$$t = \frac{F}{\pi d \sigma_{ALL}} = \frac{8900}{\pi d (40{,}000)} = \frac{.071}{d}$$

SECTION[1]	d	t
1-1	3.35	N/A
2-2	3.55	N/A
3-3	3.55	.0200
4-4	3.62	.0196
5-5	5.08	.0140
6-6	6.43	.0110
7-7	6.95	.0102

(1) SEE PAGE III-7

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SKETCH NO.

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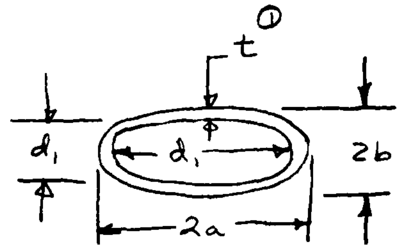
BLDG. ______ TITLE A-37B LANDING GEAR

OUTER CYLINDER

TORSIONAL STRESSES
FOR SHAPE SHOWN



$$S = \frac{T}{2\pi t\left(a-\frac{1}{2}t\right)\left(b-\frac{1}{2}t\right)}$$

$$= \frac{T}{\pi t\,(d_1+t)(b_1+t)}$$

SECTION ②	b_1	d_1	S/T $t=.1$	$t=.2$	$t=.3$	$t=.4$
3-3	3.25	3.25	.284	.134	.084	.060
4-4	↓	3.80	.244	.115	.073	.052
5-5		6.70	.140	.067	.043	.031
6-6		9.40	.100	.048	.031	.022
7-7	↓	10.4	.090	.044	.028	.020

SECTION ③	S FOR T = 78,000 IN-LB $t=.1$	$t=.2$	$t=.3$	$t=.4$
3-3	22,152	10,452	6,552	4680
4-4	19,032	8,970	5,694	4056
5-5	10,920	5,226	3,354	2418
6-6	7,800	3744	2,418	1716
7-7	7,020	3,432	2,184	1560

① t = THICKNESS ⊥ TO OUTER CYLINDER/TRUNNION ℄ LINES
SEE PAGE III-7

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PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JonB

BLDG. ______ TITLE A-37B LANDING GEAR

OUTER CYLINDER
IN-PLANE SHEAR
DUE TO TRANSVERSE
SHEAR LOAD

$$\tau = \frac{2V}{A}$$

SECTION	V (1)	A (FOR t = .1")	τ (FOR t = .1")
3-3	20,700	1.05	39,429
4-4	17,500 ~~[illegible]~~	1.14	30,702
5-5	18,650	1.59	23,459
6-6	18,650	2.02	18,466
7-7	12,150	2.18	11,147

SECTION	A (t = .2")	τ (t = .2")	A (t = .3")	τ (t = .3")	A (t = .4")	τ (t = .4")
3-3	2.17	19,600	3.35	12,350	4.59	9040
4-4	2.34	15,000	3.61	9,700	4.93	7100
5-5	3.25	11,500	4.97	7,550	6.75	5530
6-6	4.10	9,120	6.24	5,990	8.45	4410
7-7	4.41	5,520	6.72	3,620	9.08	2690

(1) SEE PAGE III-7

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BLDG. ______ TITLE ______

OUTER CYLINDER/TRUNNION
IN-PLANE SHEAR STRESS
COMBINED TORSIONAL
TRANSVERSE SHEAR LOADS

$$\tau_T = V + T$$

(1)

SECTION	FOR t = .1 TORSION	V	τ_T	t = .2 TORSION	V	τ_T
3-3	22,152	39429	61,581	10,45.	19,600	30,052
4-4	19,032	30,702	49,734	8,970	15,000	23,970
5-5	10,920	23,459	34,379	5,226	11,500	16,726
6-6	7,800	18,466	26,266	3,744	9,120	12,864
7-7	7,020	11,147	18,167	3,432	5,520	8,952

FOR t = .3

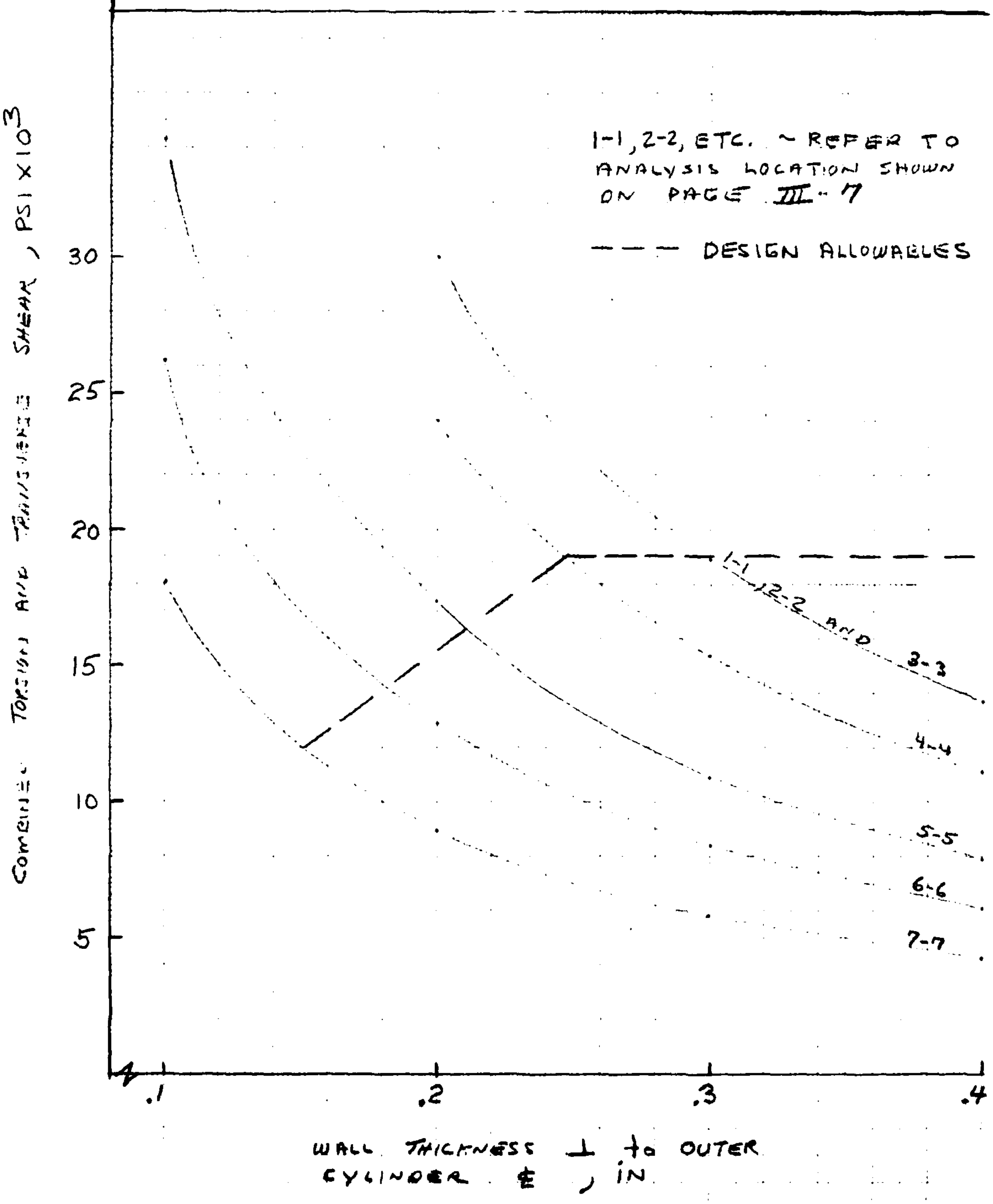
SECTION	TORSION	V	τ_T
3-3	6,552	12,350	18,902
4-4	5,694	9,700	15,394
5-5	3,354	7,550	10,904
6-6	2,418	5990	8,408
7-7	2,184	3,620	5,804

FOR t = .4

SECION	TORSION	V	τ_T
3-3	4,680	9040	13,720
4-4	4056	7100	11,156
5-5	2,418	5530	7,948
6-6	1,716	4410	6,126
7-7	1,560	2690	4,250

(1) see p. III-7

FIG OUTER CYLINDER IN-PLANE SHEAR STRESSES DUE TO TORSIONAL AND TRANSVERSE SHEAR LOADS



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OUTER CYLINDER

BENDING STRESSES

$$\sigma_z = \frac{M_y c}{I}$$

SECTION ①	M_y	c	I	σ_z for t = .1
1-1	16,000	1.73	1.48	18,700
2-2	63,000	1.73	1.48	72,500
3-3	135,000	1.73	.	157,000
4-4	176,000	2.0	2.04	168,000
5-5	223000	3.45	7.65	101,000
6-6	264,000	4.8	17.32	73,200
7-7	281,000	5.3	22.25	67,000

t = .2		t = .3		t = .4	
I	σ_z	I	σ_z	I	σ_z
3.24	8,550	5.31	5212	7.23	3581
3.24	33,200	5.31	20,200	7.23	13,876
3.24	72,000	5.31	43,983	7.23	30,213
4.52	77,876	7.35	47,891	10.6	33,[illegible]08
16.14	47,657	25.54	30,123	35.99	21,436
36.13	35,073	56.48	22,436	78.47	16,149
46.25	32,201	72.09	20,659	99.84	14,917

① SEE PAGE III-7

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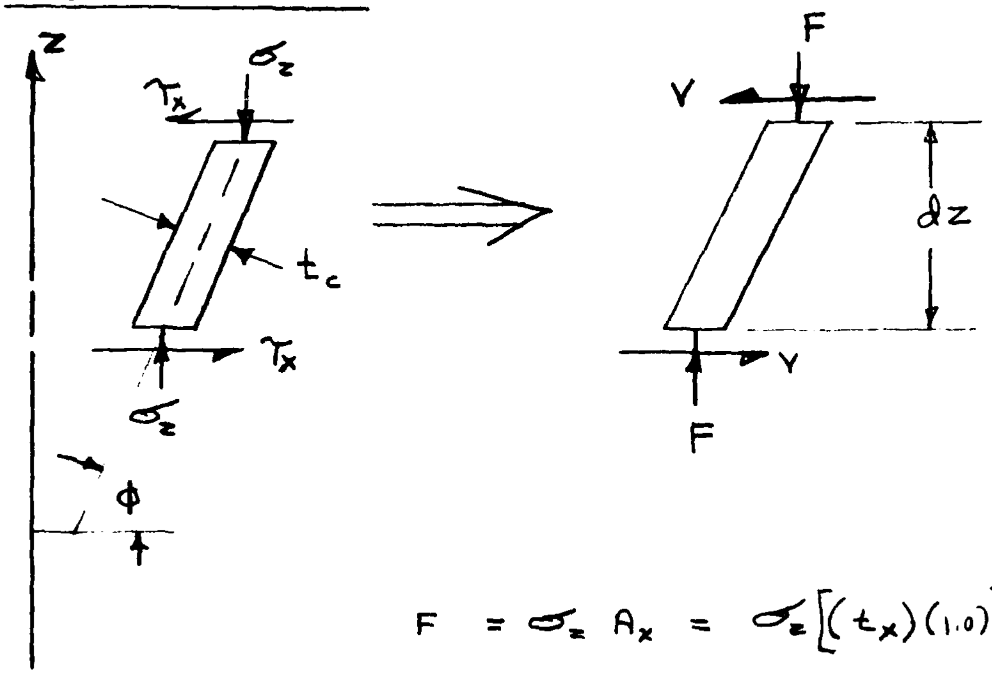
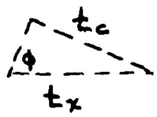
SKETCH NO. III-26

PLANT ______ PROJECT NO. ______ DATE ______ AUTHOR ______

BLDG. ______ TITLE ______

OUTER CYLINDER
FORCES IN CONE
SECTION





$$F = \sigma_z A_x = \sigma_z\left[(t_x)(1.0)\right] = \sigma_z t_x$$

$$V = \tau_x A_x = \tau_x\left[(t_x)(1.0)\right] = \tau_x t_x$$

BUT,

$$\sin\phi = t_c / t_x$$

$$t_x = t_c / \sin\phi \quad , t_c = t_x \sin\phi$$

$$F = \frac{\sigma_z t_c}{\sin\phi} \quad \text{OR} \quad \sigma_z t_x \quad \text{lb/in}$$

$$V = \frac{V_x t_c}{\sin\phi} \quad \text{OR} \quad \tau_x t_x \quad \text{lb/in}$$

HERCULES INCORPORATED
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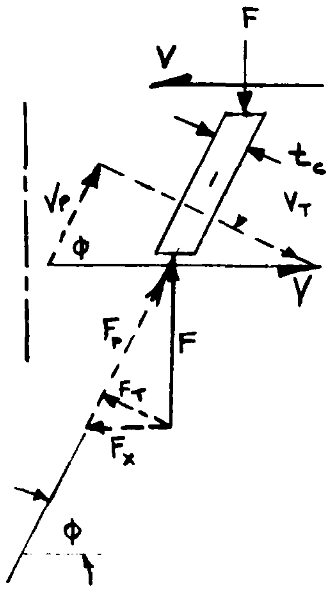
SKETCH NO. ______

PLANT ______ PROJECT NO. ______ DATE ______ AUTHOR JMB

BLDG. ______ TITLE A-37 B LANDING GEAR

OUTER CYLINDER
STRESSES IN CONE
SECTION



$$\sin\phi = F/F_P \quad , \quad F_P = F/\sin\phi$$

$$\tan\phi = F/F_x \quad , \quad F_x = F/\tan\phi$$

$$\sin\phi = F_T/F_x \quad , \quad F_T = F_x \sin\phi$$

$$F_T = \frac{F}{\tan\phi}\sin\phi = F\cos\phi$$

$$\sin\phi = \frac{V_T}{V} \quad , \quad V_T = V\sin\phi$$

$$\cos\phi = \frac{V_P}{V} \quad , \quad V_P = V\cos\phi$$

FORCE PARALLEL TO PLIES

$$F_{P_T} = F_P + V_P = \frac{F}{\sin\phi} + V\cos\phi$$

FORCE TRANSVERSE TO FIBERS

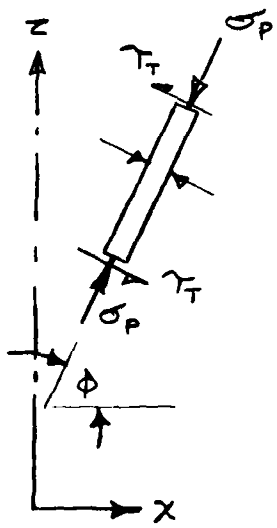
$$F_{T_T} = V_T - F_T = V\sin\phi - F\cos\phi$$

STRESSES

$$\sigma_P = \frac{F_{PT}}{A} = \frac{F_{PT}}{t_c \times 1} = F_{PT}/t_c$$

$$\tau_T = \frac{F_{TT}}{A} = \frac{F_{TT}}{t_c \times 1} = F_{TT}/t_c$$

OUTER CYLINDER
STRESSES IN CONE
SECTION



$$\sigma_\phi = \frac{F_{PT}}{t_c} = \frac{F_{PT}}{t_x \sin\phi}$$

$$= \frac{1}{t_x \sin\phi}\left[\frac{F}{\sin\phi} + V\cos\phi\right]$$

$$= \frac{1}{t_x \sin\phi}\left[\frac{\sigma_z t_x}{\sin\phi} + \tau_x t_x \cos\phi\right]$$

$$\boxed{\sigma_p = \frac{\sigma_z}{\sin^2\phi} + \frac{\tau_x}{\tan\phi}}$$

$$\tau_T = \frac{F_{\tau_T}}{t_c} = \frac{F_{\tau_T}}{t_x \sin\phi}$$

$$= \frac{-F\cos\phi + V\sin\phi}{t_x \sin\phi} = \frac{1}{t_x \sin\phi}\left[-\sigma_z t_x \cos\phi + \tau_x t_x \sin\phi\right]$$

$$\boxed{\tau_T = \tau_x - \frac{\sigma_z}{\tan\phi}}$$

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SKETCH NO.

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JWB

BLDG. ______ TITLE A-37 B LANDING GEAR

OUTER CYLINDER
STRESSES ∥ AND ⊥
WALL STRUCTURE

$\phi = 70°$

$$\sigma_P = \frac{\sigma_z}{\sin^2\phi} + \frac{.3\,T_x}{\tan\phi} \qquad \tau_T = .3T_x - \frac{\sigma_z}{\tan\phi}$$

FOR $t_x = .1$, $t_c = .094$

SECTION (1)	σ_z	T_x	σ_P	τ_T
4-4	168,000	30,702	193,613	-51,946
5-5	101,000	23,459	116,945	-29,729
6-6	73,200	18,406	82,901	-21,107
7-7	67,000	11,147	77,095	-21,046

FOR $t_x = .2$, $t_c = .188$

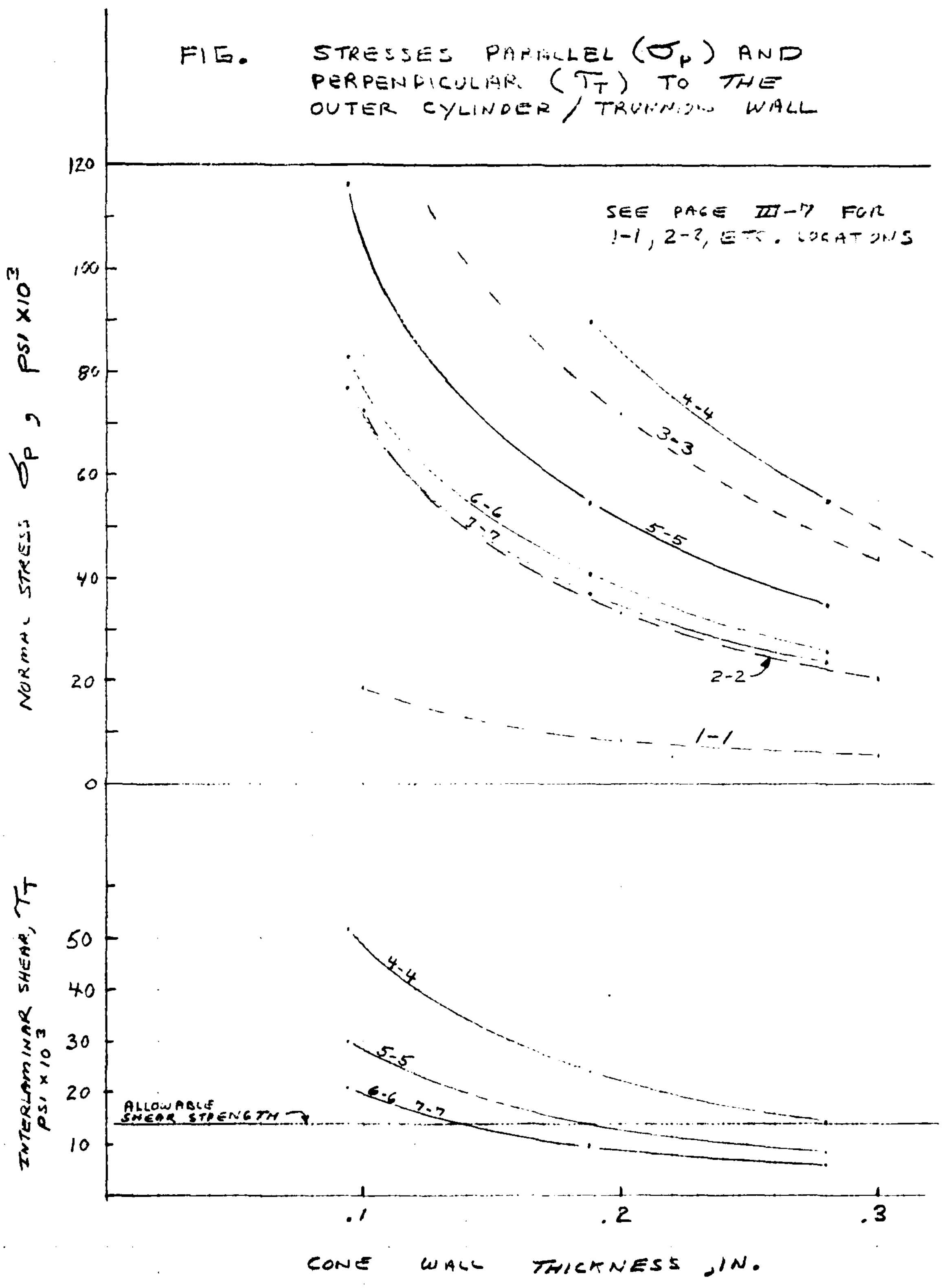
4-4	77,876	15,000	89,823	-23,849
5-5	47,667	11,500	55,239	-13,962
6-6	35,073	9,120	40,716	-10,031
7-7	32,202	5,520	37,072	-10,066

FOR $t_x = .3$, $t_c = .282$

47,891	9700	55,296	-14,523
30,123	7550	34,939	-8,701
22,436	5990	26,063	-6,370
20,659	3620	23,791	-6,434

(1) see p. III-7

FIG. STRESSES PARALLEL (σ_p) AND PERPENDICULAR (τ_T) TO THE OUTER CYLINDER / TRUNNION WALL



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SKETCH NO.

PLANT ____ PROJECT NO. ____ DATE 2-73 AUTHOR JMB

BLDG. ____ TITLE A-37 B LANDING GEAR

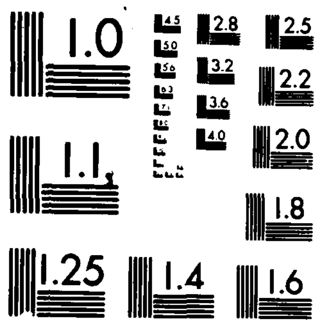
OUTER CYLINDER / TRUNNION REQUIRED DESIGN THICKNESSES

	DESIGN ALLOWABLES			REQUIRED THICKNESSES FOR						
SECTION (4)	σ	INTER-LAMINAR SHEAR	τ	INTER-LAMINAR SHEAR	τ_{xy}	σ_A (1)	σ_b (2)	σ_T (3)	t_{major}	t_{minor}
1-1	50,000	14,000	19,000	<.05	.3	—	<.03	<.03	.3	.3
2-2	50,000	14,000	19,000	<.05	.3	—	.140	.140	.3	"
3-3	50,000	14,000	19,000	<.05	.3	.020	.270	.290	.3	"
4-4	50,000	14,000	19,000	.285	.25	.020	.300	.320	.320	.32
5-5	50,000	14,000	16,500	.190	.21	.014	.205	.219	.219	.21
6-6	50,000	14,000	14,000	.140	.18	.011	.155	.166	.166	.18
7-7	50,000	14,000	12,000	.140	.12	.010	.140	.150	.150	.12

(1) σ_A = AXIAL STRESS
(2) σ_b = BENDING STRESS
(3) σ_T = $\sigma_A + \sigma_b$
(4) SEE PAGE III-7

AD-A129 206 GRAPHITE COMPOSITE LANDING GEAR COMPONENTS VOLUME II TECHNICAL APPENDICES(U) HERCULES INC MAGNA UT BACCHUS WORKS L C JENSEN ET AL. JUN 77 AFFDL-TR-77-20-VOL-2 2/3

UNCLASSIFIED F33615-72-C-1725 F/G 1/3 . NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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SKETCH NO.

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG ______ TITLE A-37 B LANDING GEAR

OUTER CYLINDER / TRUNNION

SECTION (5)	INNER TUBES ±45	INNER TUBES 0°	OUTER STRUCTURE WINDINGS (4)	OUTER STRUCTURE 0°	OUTER STRUCTURE t_{minor} ANGLE PLIES	OUTER STRUCTURE t_{major} ANGLE PLIES	TOTAL LOAD CARRING THICKNESSES (1) t_{minor} (2)	TOTAL LOAD CARRING THICKNESSES (1) t_{major} (3)
1-1	.025	.025	.125	.125	—	—	.3	.3
2-2			.125		—	—	.3	.3
3-3			.125		—	—	.3	.3
4-4			.098		.152	.076	.250	.3
5-5			.050		.160	.080	.210	.255
6-6			.036		.144	.072	.180	.233
7-7			.034		.086	.043	.120	.202

(1) INCLUDES INNER TUBE THICKNESSES IN SECTIONS 1-1, 2-2 AND 3-3 ONLY.

(2) $t_{minor} = t_{winding} + t_{minor\,(angle)}$

(3) $t_{major} = t_{windings} + t_{0^\circ} + t_{major\,(angles)}$

(4) FOR $\alpha_1 = 60^\circ$ SEE P. III-18

(5) SEE PAGE III-7

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III-33

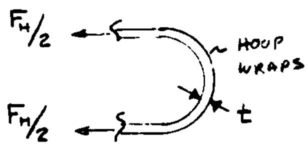
SKETCH NO. ______

PLANT ______ PROJECT NO. ______ DATE ______ AUTHOR ______

BLDG. ______ TITLE ______

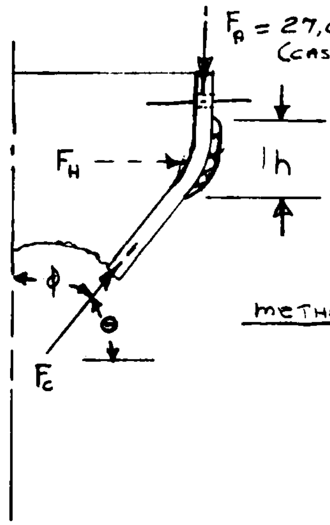
OUTER CYLINDER
REQ 90° PLIES AT
AIRCRAFT/GEAR ATTACHMENT

$\phi = 20°$, $\theta = 90 - \phi = 70°$



$\tan\theta = \dfrac{F_A}{F_H}$

$F_H = F_A / \tan 70° = \dfrac{27{,}600^{\#}}{2.748} = 10{,}000^{\#}$



$h = 2.0$

σ_{ALL} = ALLOWABLE ULT. HOOP STRESS = 138,000 psi

method# 1

$$\sigma_H = k \frac{F_H/2}{h\,t} = 2.0 \left[\frac{5{,}000}{2\,t}\right]$$

$$t = \frac{5{,}000}{\sigma_{ALL}} = \frac{5{,}000}{138{,}000}$$

$t = 0.036$ IN

USE $t = 0.040$

① BASED UPON COS ϕ DISTRIBUTION

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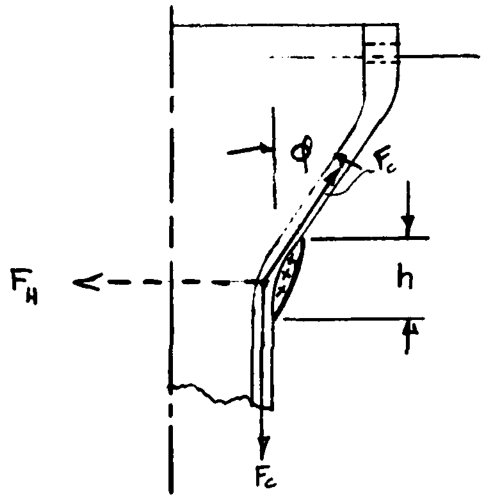
III-34

SKETCH NO. ______

PLANT ______ PROJECT NO. ______ DATE ______ AUTHOR ______

BLDG. ______ TITLE ______

OUTER CYLINDER
REQ. 90° PLIES
AT CYLINDER/CONE
JUNCTURE



$\phi = 20°$

$h = 2.0$

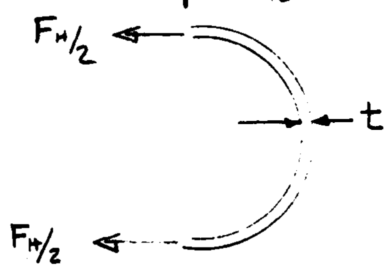
σ_N at SECTION 4-4 = 84,000 PSI
FOR $t = .20$ (SEE FIG __)

$\therefore$

$$F_{c_{max}} = A\,\sigma_N = (.2)(84{,}000)$$
$$= 16{,}800^{\#}$$

$$\cos(90-\phi) = F_H / F_c$$

$$F_H = 16{,}800\,(.342) = 5{,}746^{\#}$$



$$\sigma_H = k\,\frac{F_H/2}{ht} = \frac{2\,(2{,}873)}{2\,t}$$

$$t = \frac{2873}{\sigma_{ALL}} = \frac{2873}{138{,}000}$$

$$t = \underline{\underline{0.021 \text{ in}}}$$

USE $\underline{\underline{t = .025 \text{ in}}}$

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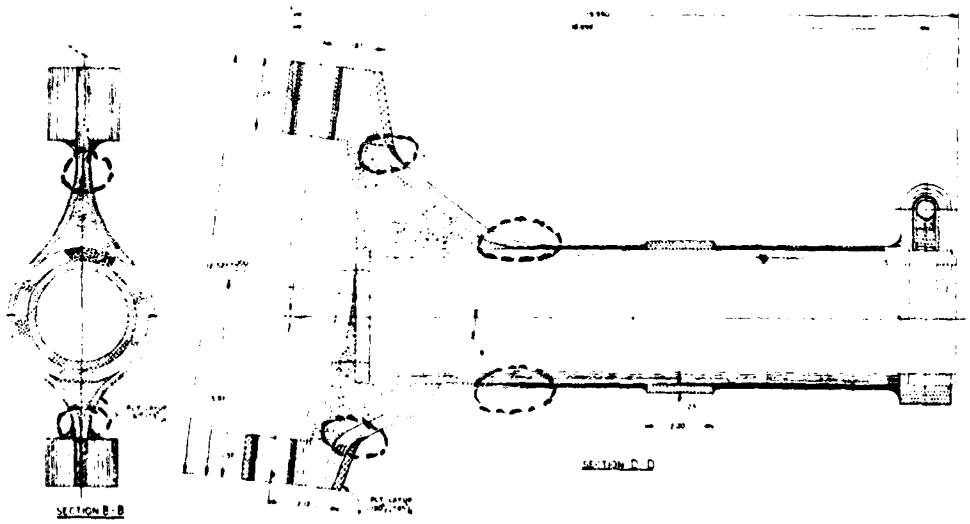
PLANT ________ PROJECT NO. ________ DATE 10-30-72 AUTHOR J. N. BURNS

BLDG. ________ TITLE A-37B LANDING GEAR

PROPOSAL DESIGN

THE DESIGN OF A COMPOSITE TRUNNION IS A DIFFICULT TASK BECAUSE IT'S A 3D LOADED STRUCTURE. COMPOSITES HAVE EXCELLANT 1-D PROPERTIES, FAIR 2D PROPERTIES BUT POOR PROPERTIES IN THE 3rd DIRECTION (TRANSVERSE PROPERTIES). CONSEQUENTLY, THE DESIGNER ATTEMPTS TO MAXIMIZE THE USE OF THE 1-D AND 2-D PROPERTIES BY SELECTING THE PROPER STRUCTURAL GEOMETRIES. HOWEVER, IT IS VERY DIFFICULT TO ELEMINATE THE CONDITION WHERE INTERLAMINAR SHEAR LIMITS THE DESIGN.

THE PROPOSAL DESIGN IS ESSENTIALLY A BONDED ASSEMBLAGE OF 2-D COMPOSITE SUB COMPONENTS. (SEE FIGURE 1) THE MAJOR PROBLEM WITH THE DESIGN IS GEOMETRY WHICH PLACES THE BONDS BETWEEN VARIOUS SUBCOMPONENTS INTO AN UNDESIRABLE CLEAVAGE TYPE OF STRESS STATE.



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III-36
SKETCH NO.

PLANT ______ PROJECT NO. ______ DATE 10-30-72 AUTHOR J.N. BURNS

BLDG. ______ TITLE ______

THERE ARE FOUR BASIC TYPES OF STRESS ENCOUNTERED IN STRUCTURAL BONDING: TENSILE, SHEAR, CLEAVAGE AND PEEL.

The basic types of structural stress.

Tensile stress results when forces perpendicular to the plane of the joint are distributed uniformly over the entire bonded area. If the joint is properly designed, all of the adhesive will contribute to the strength of the bond. Unfortunately, loads rarely are axial and often develop into cleavage stresses. This can be prevented, however, by physical restraints.

Shear stress occurs when force is applied parallel to the plane of the joint and distributed uniformly over the bonded area. Most joints are designed for this type of stress. Here, too, all of the adhesive contributes to the strength of the bond. Since shear bonds are relatively simple to make, joints which depend upon an adhesive's shear strength are more common than tensile joints.

Shear loads concentrate at the ends of a lap joint and only slightly affect the joint's middle portion. Loads resulting from bending of the material can be reduced either by beveling the ends to allow bending, removing material to reduce stiffness, increasing flexibility by inserting a less rigid material between stiff adherends, or bonding flexible doublers on the outer surfaces at points where bending occurs.

Cleavage, an undesirable type of stress, is similar to tensile stress because force is applied perpendicular to the plane of the joint. Cleavage stress, however, is concentrated along one side of the bond, while other areas remain almost unstressed. Cleavage conditions should be avoided in the design of a joint.

Peel is another undesirable type of stress. It is unlike shear stress in that force is applied approximately perpendicular to the plane of the joint. Peel stress, however, is confined to a very thin line at the edge of the bond. When peel occurs the remaining bond area makes no contribution to the strength of the joint.

Added width in a joint can increase the resistance to peel stress, or you can lap the more flexible end over the stiffer adherend. You can also inhibit peel by stiffening the end of the flexible member: that is, by adding either bonded doublers or a mechanical stop such as a rivet, or by recessing the end of the flexible member.

Methods of reducing peel stresses at the point where peel starts.

A joint is rarely subjected to just one type of stress. Commonly, several types act together to weaken the joint. This fact should be borne in mind when designing a joint.

Structural adhesives have the highest resistance to tensile or shear stresses, and designs which subject the bond to cleavage or peel forces should be avoided. The working area of the bond should be as large as possible. Strength is directly proportional to the bond width; increasing the width will always increase the strength of a joint. Increasing the depth, or amount of overlap, does not always increase the bond strength, however. Peel stress is distributed only by increasing the width of a joint; thus depth has no effect.

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III-37

SKETCH NO. ______

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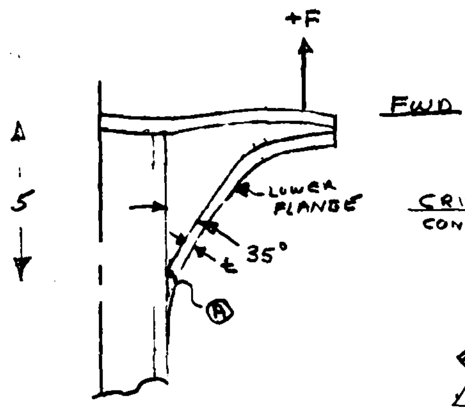
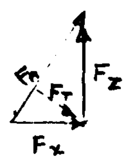
BLDG. ______ TITLE ______



CRITICAL CLEAVAGE LOAD CONDITION: LOAD CONDITION 4A WHERE F = 20,908 #

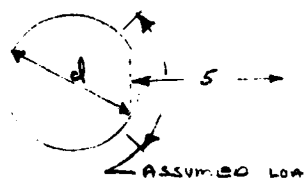


$F_x = \frac{5F}{5} = 20{,}908$ #

$F_z = F_x \tan 35° = 14{,}640$ #

$F_A = F_x/\cos 35° = 25{,}524$ #

$F_T = \sin 35° (F_x) = 11{,}992$



ASSUMED LOAD CARRYING AREA,

$A = (.25)\pi d\, 2t$

$= (.25)\pi(4)(2)(.2)$

$= 1.257 \text{ in}^2$

TENSILE STRESS @ A

$\sigma_T = F_x/A = \frac{20{,}908}{1.257 \text{ in}^2} = 16{,}633$ psi

ALLOWABLE ~ 10,000 psi

m.s. = −.66

CRITICAL INTERLAMINAR SHEAR @ A : LOAD CONDITION 5A, F = 26,827 #

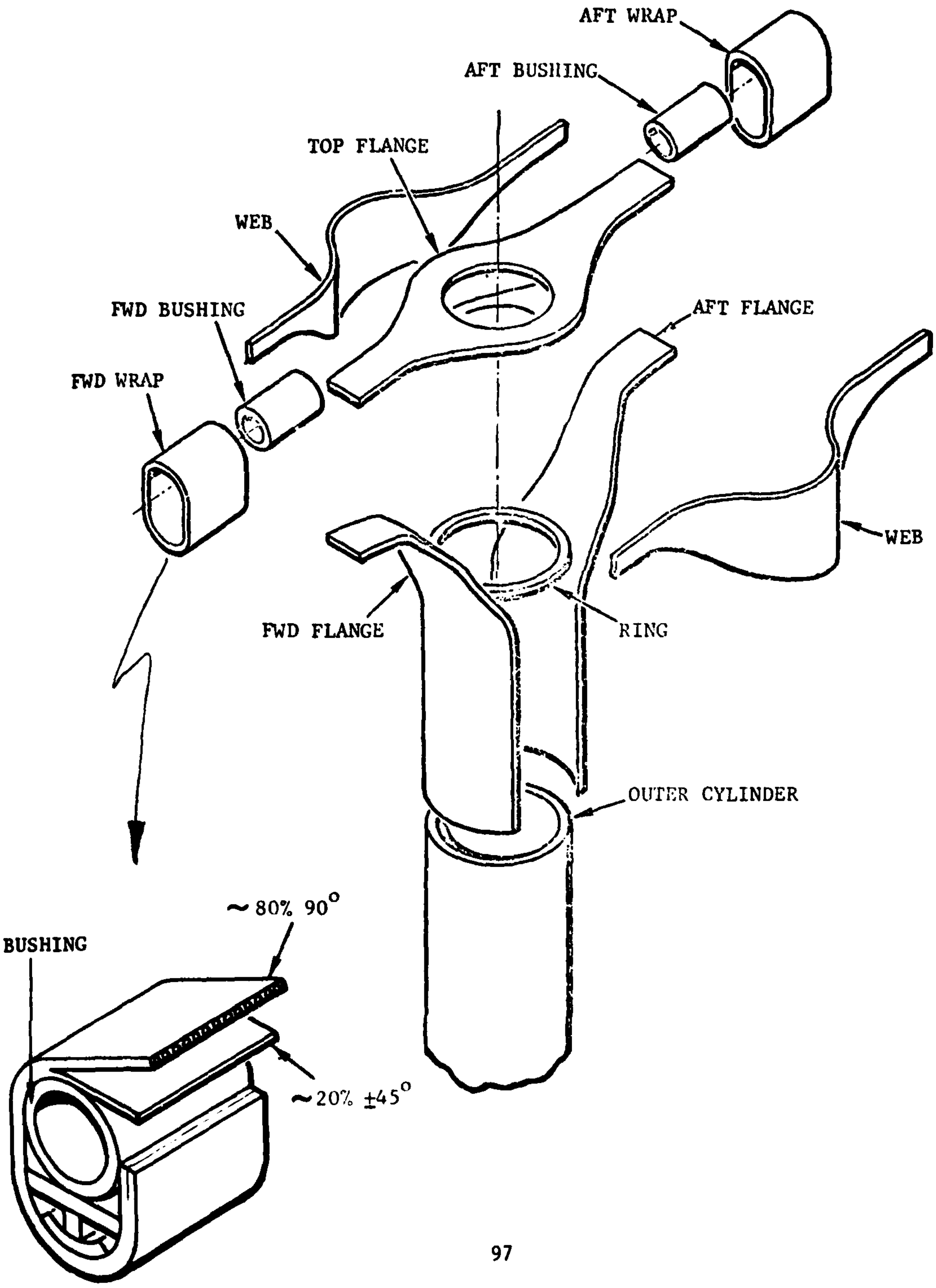
SHEAR FOR CONDITION 4A $\quad \tau = \frac{F_x}{A} = \frac{20{,}908}{.25\pi d t} = \frac{20{,}908}{.25\pi(4).2} = 33{,}270$ psi $\quad$ ALLOWABLE = 10,000

m.s. = − 2.33

SHEAR FOR CONDITION 5A $\quad \tau = \frac{26{,}827}{20{,}908} \times 33{,}270 = 42{,}685$ psi $\quad$ m.s. = − 3.27

CONCLUSION: THE ABOVE (−) MARGINS OF SAFETY SHOW THE PROPOSAL DESIGN TO BE STRUCTURAL INADEQUATE. POSITIVE m.s. COULD BE PREDICTED BY INCREASING THE LOWER FLANGE THICKNESS. THIS, HOWEVER, DOES NOT SOLVE THE CLEAVAGE PROBLEM THAT EXISTS AT POINT A. STRESS CONSENTRATIONS AT THIS POINT CANNOT BE PREDICTED BY THIS HAND ANALYSIS. IT IS RECOMMENDED THE DESIGN BE CHANGED TO ELIMINATE THE CLEAVAGE CONDITIONS.

TRUNNION DESIGN



APPENDIX A
PART IV

DESIGN ANALYSIS
OF
THE PISTON

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SKETCH NO. III . 1

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR James N. Burns

BLDG. ______ TITLE A-37 B LANDING GEAR

PISTON DESIGN

CONFIGURATION

SEE FIGURE 1 WT. = 3.89 #

LOADS

APPLIED LOADS PER FIGURE 2
SHEAR DIAGRAM PER FIGURE 3
MOMENT DIAGRAM PER FIGURE 4
AXIAL LOAD PER FIGURE 5
INTERNAL PRESSURE OF 1500 PSI LIMIT = 2250 PSI ULT.

PISTON LAY-UP AND MATERIAL

$[0^\circ_4/\pm 45^\circ/90^\circ]_s$ OF 2002/AS GRAPHITE EPOXY

0° IS ∥ TO PISTON ℄

DESIGN ALLOWABLES

ULTIMATE DESIGN ALLOWABLES

1. BASED UPON LIMIT INTERACTION CURVE (SEE FIGURE 6)
2. ULT. ALLOWABLE = LIMIT ALLOWABLE FROM INTERACTION CURVE TIMES 1.50
3. HOOP STRESS $= \frac{PR}{t} = 2250 \frac{(1.09)}{.49} = 5004$ PSI
4. FROM FIGURE 6, USING $\sigma_{y_t} = 5004 \times \frac{1}{1.5} = 3336$ PSI ALLOWABLES ARE:

σ_{x_t}	= 72,000	X 1.5	= 108,000	PSI
σ_{x_c}	= 72,000	X 1.5	= 108,000	PSI
σ_{y_t}	= 3336	X 1.5	= 5004	PSI
σ_{y_c}	= 3336	X 1.5	= 5004	PSI
τ_{xy}	= 13,860	X 1.5	= 20,790	PSI
INTERLAMINAR SHEAR	= 12,000			PSI

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SKETCH NO. IV.2

PLANT Bacchus PROJECT NO. ____ DATE 12-18-72 AUTHOR J.N. Burns

BLDG. ____ TITLE ____

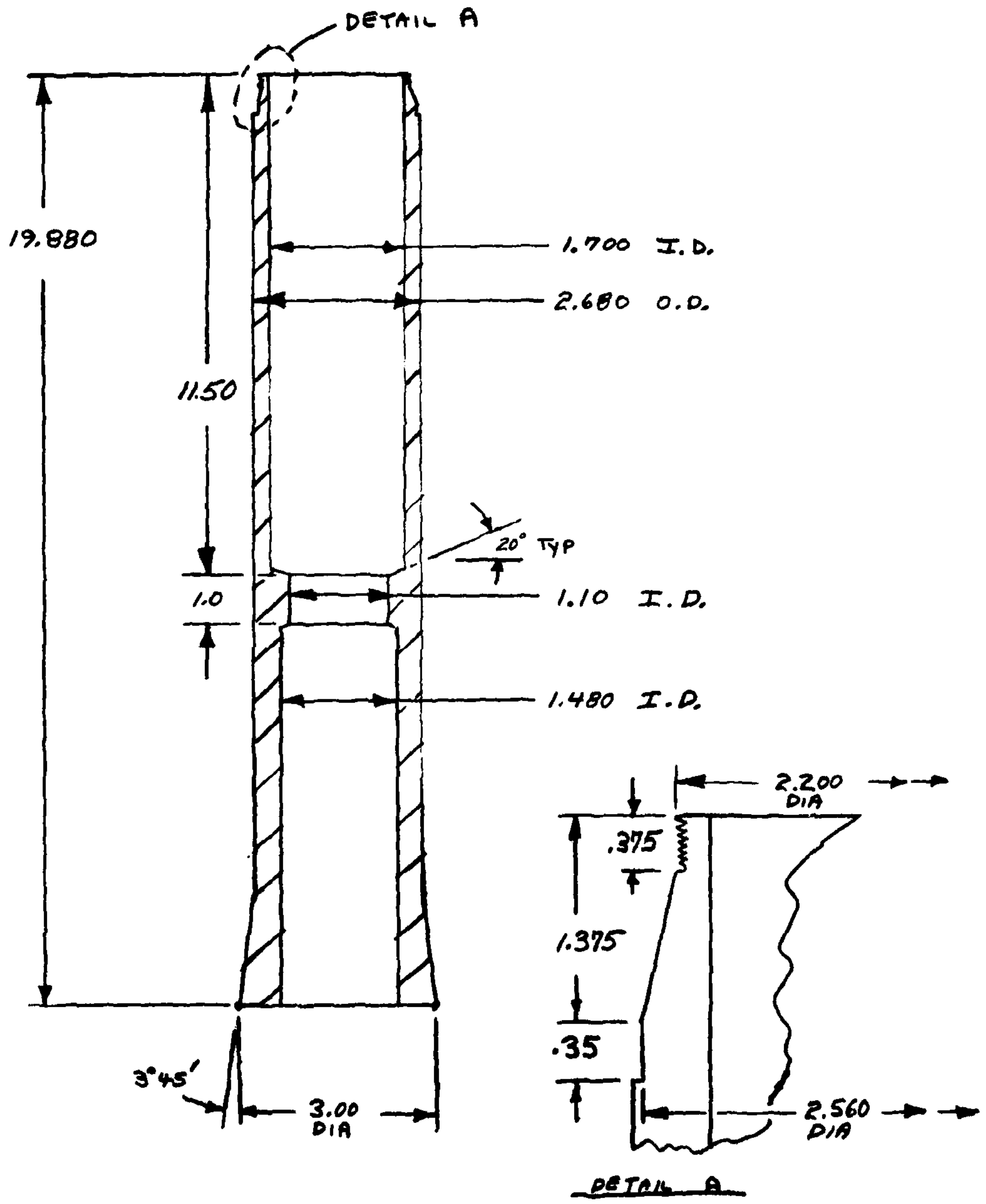

FIGURE 1
PISTON
A-37B LANDING GEAR
MAT. ~ 2002/AS

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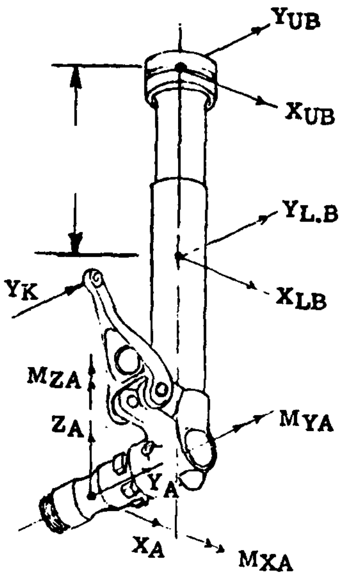
FIGURE 2

SKETCH NO. IV. 3

PLANT ______ PROJECT NO. ______ DATE 1-18-73 AUTHOR JNB

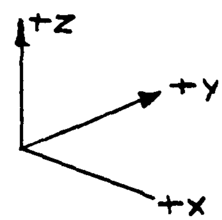
BLDG. ______ TITLE A-37 B GRAPHITE LANDING GEAR

ULTIMATE PISTON DESIGN LOADS



Piston

Forces ⟶
Moments ⟶⟶ (Left hand rule)
X Positive Aft
Y Positive Outboard
Z Positive Up



PISTON													
Load Condition			Z_A	X_A	Y_A	M_{ZA}	M_{XA}	M_{YA}	X_{LB}	$Y_{L.B}$	Y_K	X_{UB}	Y_{UB}
2 Pt. Level Landing	Max. Vert.	1A	15000	-5600	0	0	0	0	9500	15300	-5200	-3900	-10100
	Spin-up	1B	7700	7300	0	0	0	0	-12100	-3900	6600	4800	-2900
	Spring Back	1C	11700	-9700	0	0	0	0	16200	18200	-9100	-6400	-9100
Tail Down Landing	Max. Vert.	2A	13900	-9600	0	0	0	0	16000	19400	-9000	-6400	-10400
	Spring Back	2C	8300	-10400	0	0	0	0	14900	17000	-9700	-4500	-7200
Drift Landing	Right	3A	7700	-900	4700	4400	38800	0	1400	-6100	-300	-500	1800
	Left	3B	7700	-900	-6200	-5900	-51700	0	1400	21000	-1600	-500	-13300
Braked Roll		4A	11400	7200	0	0	0	-70600	-14700	-1300	6100	7500	-4800
Reverse Brake		5A	9500	-9500	0	0	0	70600	17900	14000	-8200	-8300	-5800
Right Turn		6A	11500	-1300	-5600	-5500	-48000	0	1800	19100	-1700	-500	-11600
3G Taxi		7	19200										

REFERENCE : BENDIX THIRD INTERIM REPORT - PHASE I COMPLETION APRIL 1, 1970 TO DEC. 14, 1970 ON THE FILAMENT COMPOSITE MATERIAL LANDING GEAR PROGRAM

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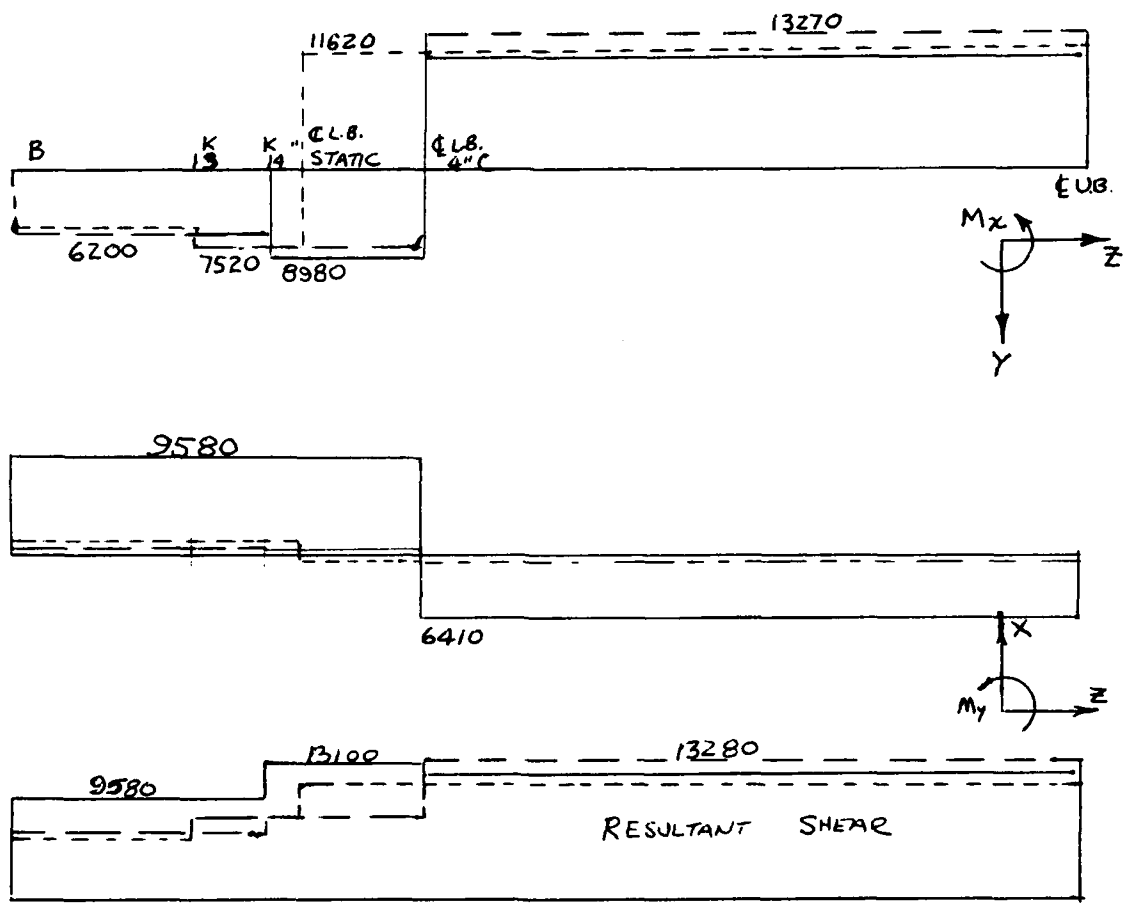
SKETCH NO. IV. 4

PLANT ______ PROJECT NO. ______ DATE ______ AUTHOR ______

BLDG. ______ TITLE ______

FIGURE 3
PISTON
SHEAR DIAGRAM (ULTIMATE)



SCALE 1 IN = 3 IN
SCALE 1 IN = 15000 LB
———— COND 2A
- - - - - COND 6A
—— —— COND 3B

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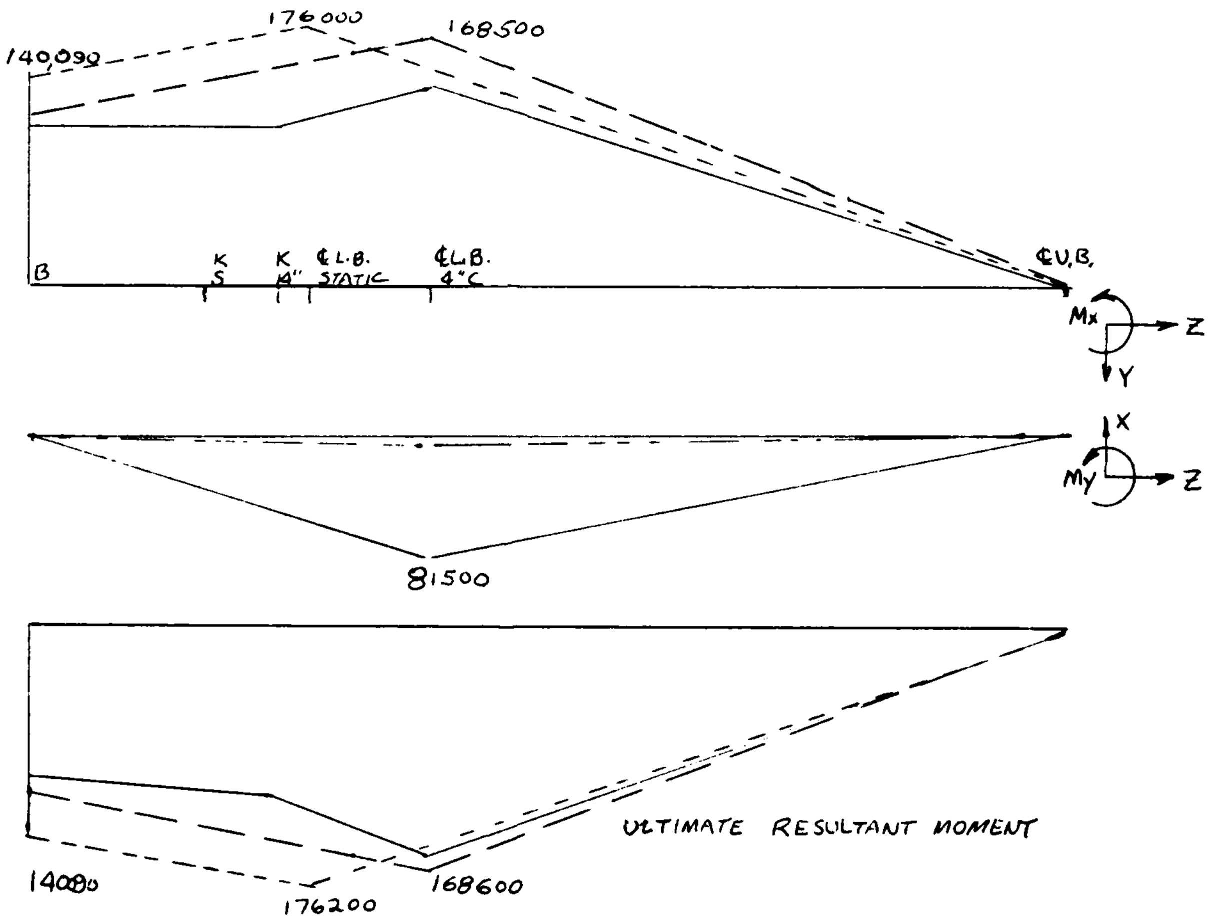
SKETCH NO. IV . 5

PLANT ____ PROJECT NO. ____ DATE ____ AUTHOR ____

BLDG. ____ TITLE ____

FIGURE 4
PISTON ULTIMATE MOMENT DIAGRAM



SCALE 1 IN = 3 IN
SCALE 1 IN = 100000 IN LB
——— COND 2A
- - - - - COND 3A
—— —— - COND 3B

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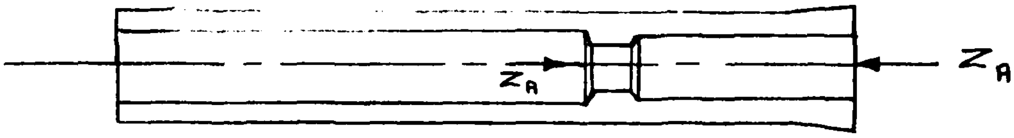
FIGURE 5
UNIFORM AXIAL
LOADING



Z_A LOADS ARE SHOWN IN FIGURE 2

FIG. 6

DESIGN PROPERTIES (77°F)
FOR
2002 AS GRAPHITE EPOXY LAMINATE $[0_4^\circ/\pm45^\circ/90^\circ]$
55% FIBER VOL.
QUASI - ORTHOTROPIC

ELASTIC CONSTANTS

$E_x = 10.83 \times 10^6$ PSI

$E_y = 4.31 \times 10^6$ PSI

$\mu_{xy} = 0.30$

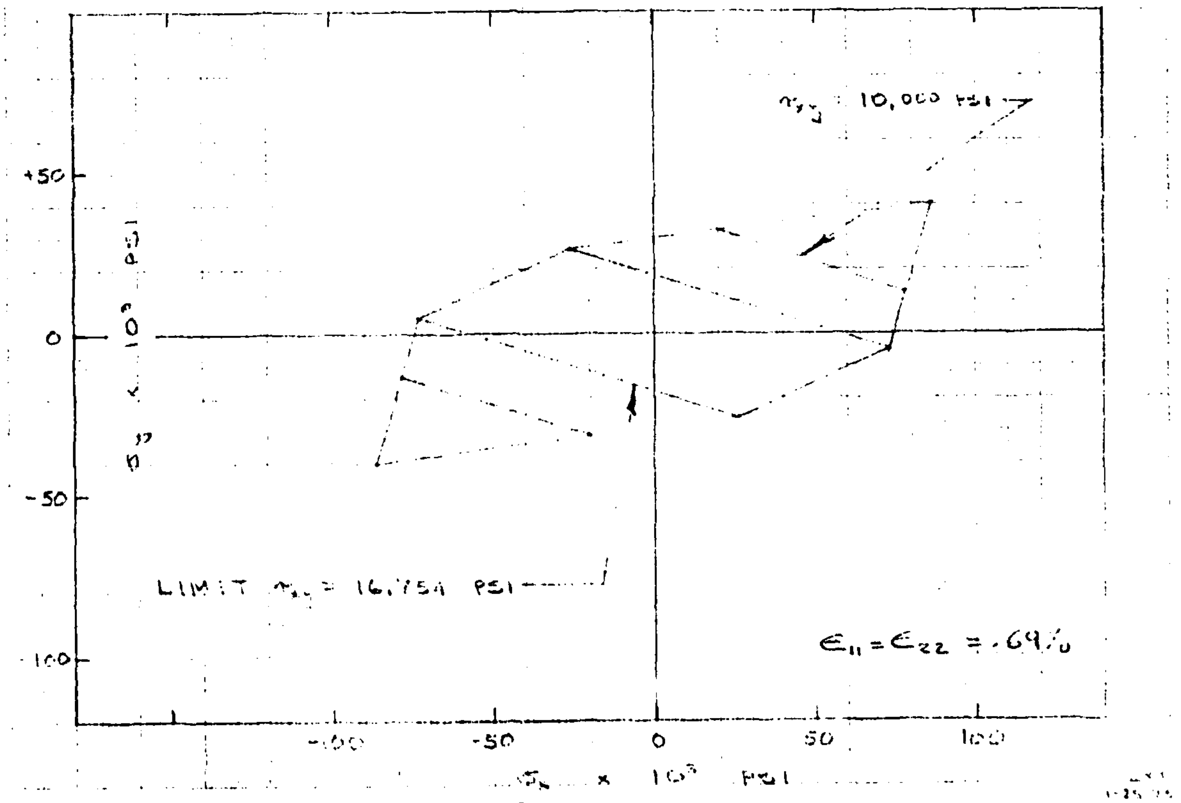
$G_{xy} = 1.69 \times 10^6$ PSI

THERMAL COEFFICIENTS

$\alpha_x = 0.118$ IN/IN/°F $\times 10^{-6}$

$\alpha_y = \pm 2.078$ IN/IN/°F $\times 10^{-6}$

"LIMIT" INTERACTION CURVE



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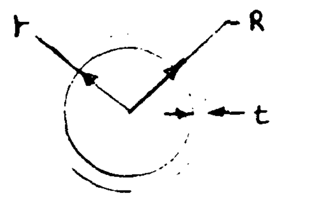
SKETCH NO. IV . 8

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR gmC

BLDG. ______ TITLE A-37 B LANDING GEAR

PISTON DESIGN

REQUIRED WALL THICKNESS FOR SHEAR



$O.D. = 2.68 \text{ in}, \quad R = 1.34$

$$F_s = \frac{2V}{A} = \frac{2V}{\pi[R^2 - r^2]}$$

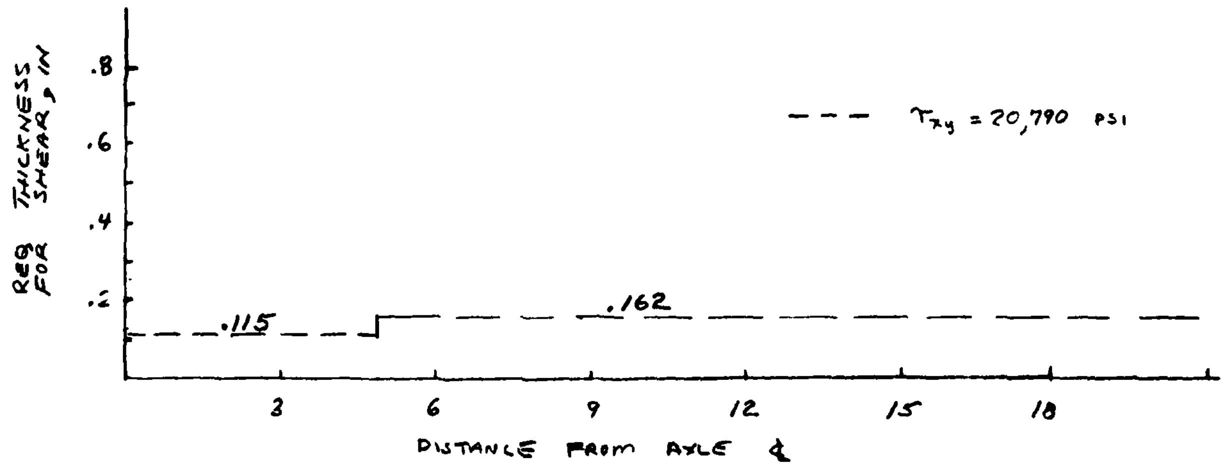
$$r^2 = R^2 - \frac{2V}{\pi F_s}$$

$F_s = F_{allowable} = \tau_{xy} = 20{,}790$ PSI

$V = 13{,}280^{\#}, \quad 13{,}100^{\#}, \quad 9580^{\#}$ (SEE FIG. 3)

$$r^2 = (1.34)^2 - \frac{2V}{\pi(20{,}790)} = 1.795 - 3.06 \times 10^{-5} V$$

V	r	t
13,280	1.178	.162
13,100	1.181	.159
9,580	1.225	.115



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SKETCH NO. IV . 9

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JmB

BLDG. ______ TITLE A-37 B LANDING GEAR

PISTON DESIGN

REQUIRED WALL THICKNESS FOR MOMENT

LOADS

SEE FIGURE 4

DESIGN ALLOWABLES

$\sigma_{x_t} = 108,000$ PSI , $\sigma_{x_c} = 108,000$ PSI

SECTION PROPERTIES

O.D. = 2.68 IN , R = C = 1.34

REQ t_w

$$F_b = \frac{mc}{I} = \frac{mc}{\frac{\pi}{4}[R^4 - r^4]}$$

$$r^4 = R^4 - \frac{mc}{F_b \frac{\pi}{4}} = (1.34)^4 - \frac{m(1.34)}{108,000(.785)} = 3.23 - 1.58 \times 10^{-5} m$$

m	r^4	r	t
140,090	1.02	1.00	.34
176,200	.45	.82	.52
168,600	.57	.87	.47
100,000	1.65	1.13	.21
50,000	2.44	1.25	.09
160,500	.69	.91	.43

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SKETCH NO. IV . 1D

PLANT ________ PROJECT NO. ________ DATE 2-73 AUTHOR JMB

BLDG. ________ TITLE A-37 B LANDING GEAR

PISTON DESIGN
ACTUAL VS. REQ. WALL
THICKNESSES

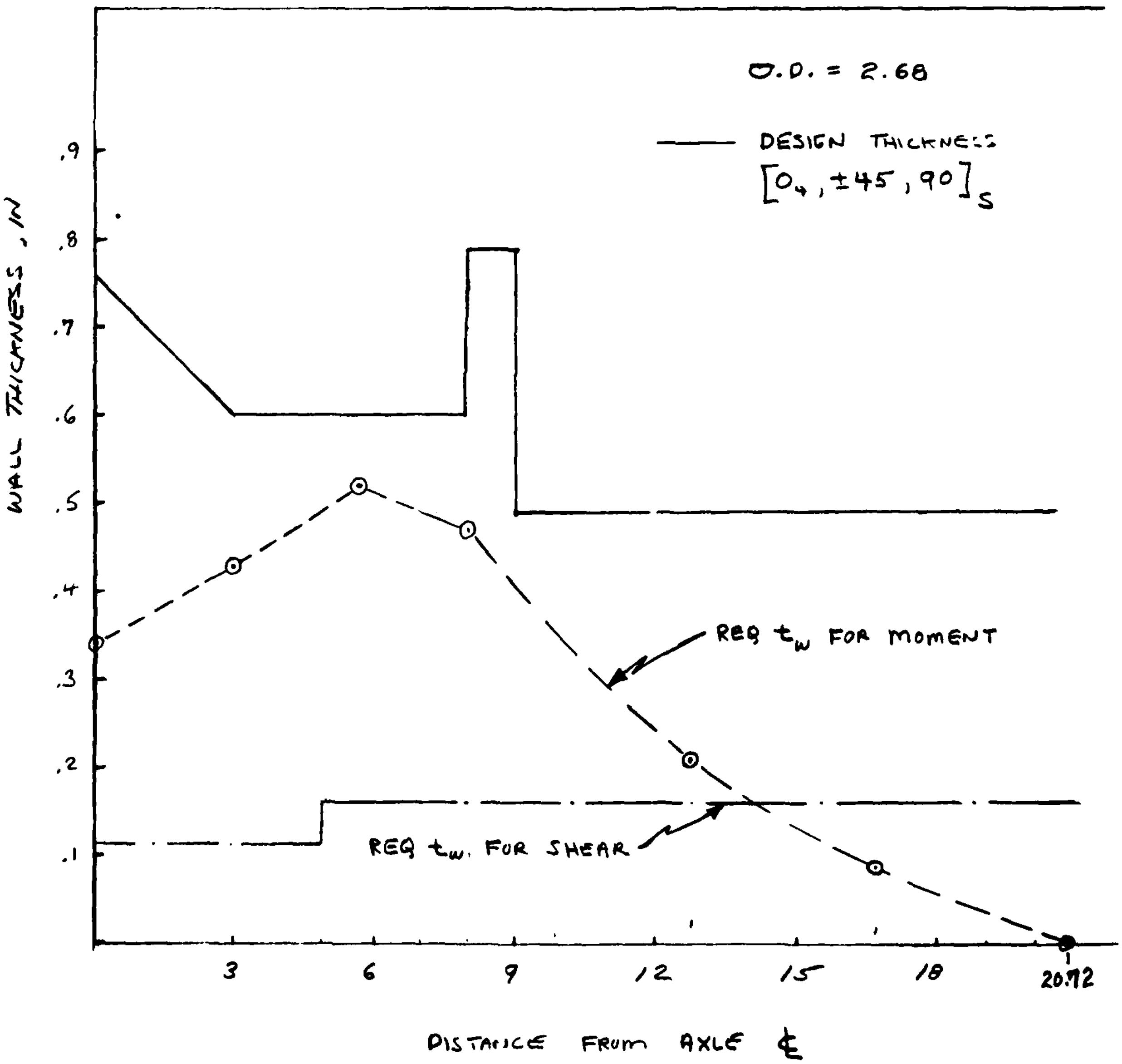

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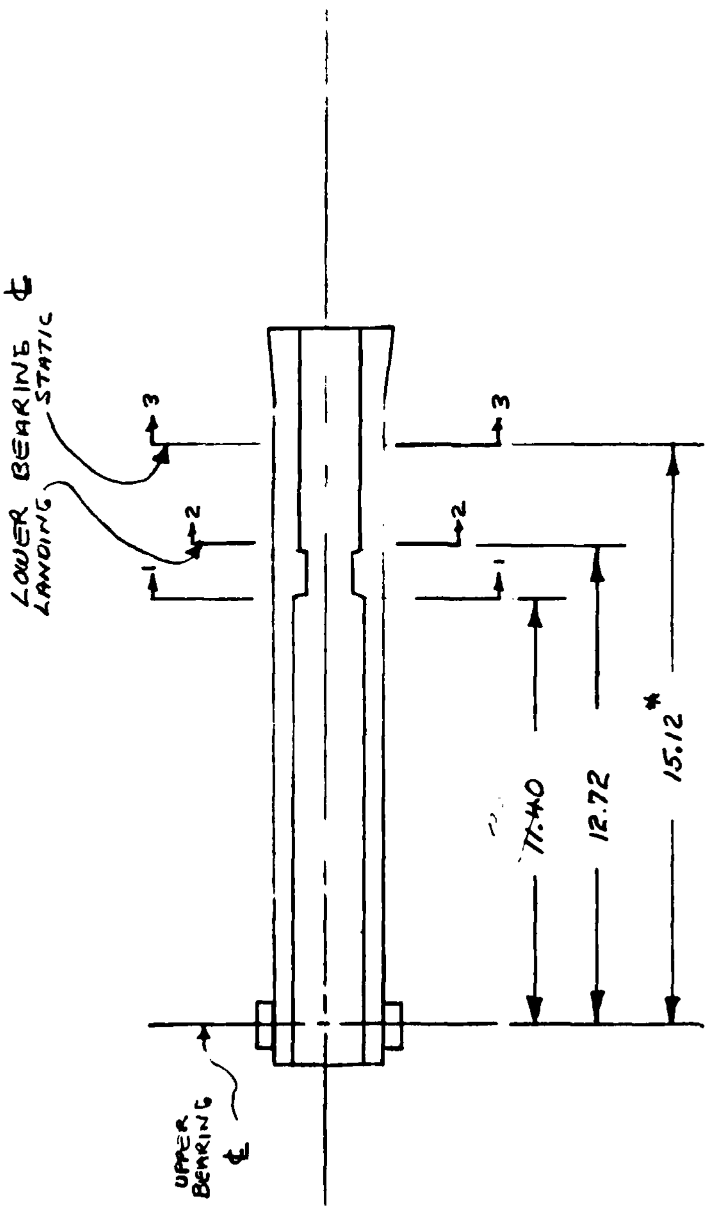
FIG 7

SKETCH NO. IV.11

PLANT ______ PROJECT NO. ______ DATE ______ AUTHOR J. N. BURNS

BLDG. ______ TITLE A-37 B GRAPHITE PISTON



* VALUE FOR WHICH LOADS WERE DEVELOPED BY BENDIX. HI COMPOSITE DESIGN WILL BE SMALL, BUT THIS VALUE IS CLOSE FOR INITIAL DESIGN

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SKETCH NO. IV .12

PLANT ________ PROJECT NO. ________ DATE 2-73 AUTHOR 9/1/63

BLDG. ________ TITLE A-37 B LANDING GEAR

STRESSES AT SECTION 1-1 (SEE FIG. 7)

SECTION PROPERTIES

$I.D. = 1.7 \qquad O.D. = 2.68 \qquad A = .785\left[(2.68)^2 - (1.7)^2\right] = 3.37 \text{ in}^2$

$I = \frac{\pi}{4}\left[R_o^4 - R_i^4\right] = .785\left[(1.34)^4 - (.85)^4\right] = 2.123 \text{ in}^4$

LOADS

SHEAR = 13,280

AXIAL LOADING = 0.0

MOMENT = 13,280 × 11.4 = 151,392 IN-LB

SHEAR STRESS

$$f_s = \frac{4}{3}\frac{V}{A}\left[1 + \frac{Dd}{D^2+d^2}\right] = \frac{4}{3}\frac{V}{A}\left[1 + \frac{(2.68)(1.7)}{(2.68)^2+(1.7)^2}\right] = 1.94\frac{V}{A}$$

$$f_s = 1.94\frac{(13,280)}{(3.37)} = \underline{7,650 \text{ PSI}} \qquad m.s. = \frac{20,790}{7,650} - 1 = \underline{+1.72}$$

NORMAL STRESS

$$F_t = F_b + F_c = \frac{mc}{I} + \frac{P}{A}$$

$$= \frac{151,392\,(1.34)}{2.123} + 0 = \underline{96,300 \text{ PSI}}$$

$$m.s. = \frac{108,000}{96,300} - 1 = \underline{+0.12}$$

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SKETCH NO. IV . 13

PLANT ________ PROJECT NO. ________ DATE 2-73 AUTHOR JAB

BLDG. ________ TITLE A-37 B LANDING GEAR

STRESSES AT SECTION 3-3 (SEE FIG 7)

SECTION PROPERTIES

$I.D. = 1.480 \qquad O.D. = 2.680 \qquad A = .785\left[(2.68)^2 - (1.48)^2\right] = 3.9 \text{ in}^2$

$I = \frac{\pi}{4}\left[R_o^4 - R_i^4\right] = .785\left[(1.34)^4 - (.74)^4\right] = 2.25 \text{ IN}^4$

LOADS (CONDITION 6A IS CRITICAL)

MOMENT = 176,200 IN-LB
SHEAR = 11,600 LB
AXIAL LOAD = 11,500 LB COMPRESSION

STRESSES

$f_s \approx 2\frac{V}{A} = \frac{2(11,600)}{3.9} = \underline{5,960} \qquad m.s. = \frac{20,790}{5,960} - 1 = \underline{+2.49}$

$f_b = \frac{mc}{I} = 176,200\frac{(1.34)}{(2.25)} = \pm 105,000$

$f_A = \frac{P}{A} = \frac{-11,500}{3.90} = -2,950$

$f_t = f_A \pm f_b = -2,950 \pm 105,00$

$= -\underline{107,950} \;,\; +\underline{102,050}$

$(-)\ m.s. = \frac{108,000}{107,950} - 1 = \underline{+0.00} \qquad (+)\ m.s. = \frac{108,000}{102,050} - 1 = \underline{+0.06}$

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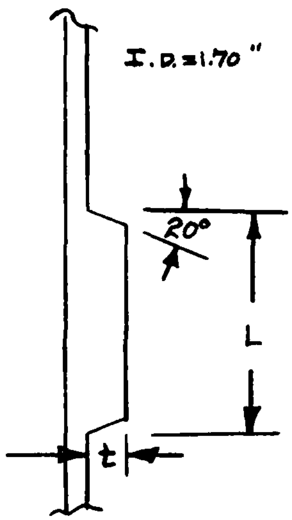
SKETCH NO. IV.14

PLANT ______ PROJECT NO. ______ DATE 2-73 AUTHOR JMB

BLDG. ______ TITLE A-37 B LANDING GEAR

PISTON

RETAINING LEDGE FOR METERING PIN



LOAD

max condition ~ 7 (3G TAXI)

$F = 19{,}200^{\#}$ ult.

PROPERTIES

$F_{su} = 10{,}000$ PSI $\quad F_{bu} = 40{,}000$ PSI

REQ. t

$$R_i = \left[R_o^2 - \frac{F}{F_{bu}\pi} \right] = \left[(.85)^2 - \frac{19{,}200}{\pi\, 40{,}000} \right]$$

$$R_i = .723 - .153 = .570$$

$$t = R_o - R_i = .85 - .57 = .28$$

REQ L

$$F_s = 3/2\, \frac{F}{A} = 3/2\, \frac{F}{\pi d l}$$

$$l = \frac{3/2\, F}{\pi d\, F_{su}} = \frac{1.5\,(19{,}200)}{\pi\,(1.7)\,(10{,}000)}$$

$l = .539$ INCHES USE, 1.0 INCHES

APPENDIX A
PART V

LOADS USED IN THE

DESIGN AND ANALYSIS

OF THE LEFT MAIN LANDING GEAR

Sketch V-1

V.A. <u>Applied Loads</u>

The following loads were calculated from the Cessna test results for the right main landing gear of the A-37B aircraft. The coordinate system used for the right gear is inverted for the left, automatically, and needs no further sign changes.

The loads calculated for the end of the axle agree with the Bendix loads table in Reference 1, except that Reference 1 has two minor errors. They have accidently switched the Fy loads for cases 3A and 3B, thereby effecting the corresponding bending moments M_z and M_x.

Limit loads tested for by Cessna are found in Reference 2. A total of eleven loading conditions are defined by Cessna and are identified and coded in Table V.1.

TABLE V.1

LOADING CONDITION CHART

Code			
1A	Landing	2 Points	Maximum vertical
1B		Level	Spin-up
1C		Landing	Spring back
2A		Tail Down	Maximum vertical
2C		Landing	Spring back
3A		Drift	Right
3B		Landing	Left
4A	Static	Braked roll	
5A		Reverse brake	
6A		Right turn	
7		2G taxi	

Limit loads for a 14,000 pound A-37B aircraft, as found by Cessna, are shown in Figure V.2 and listed in Table V.3.

Sketch V-2

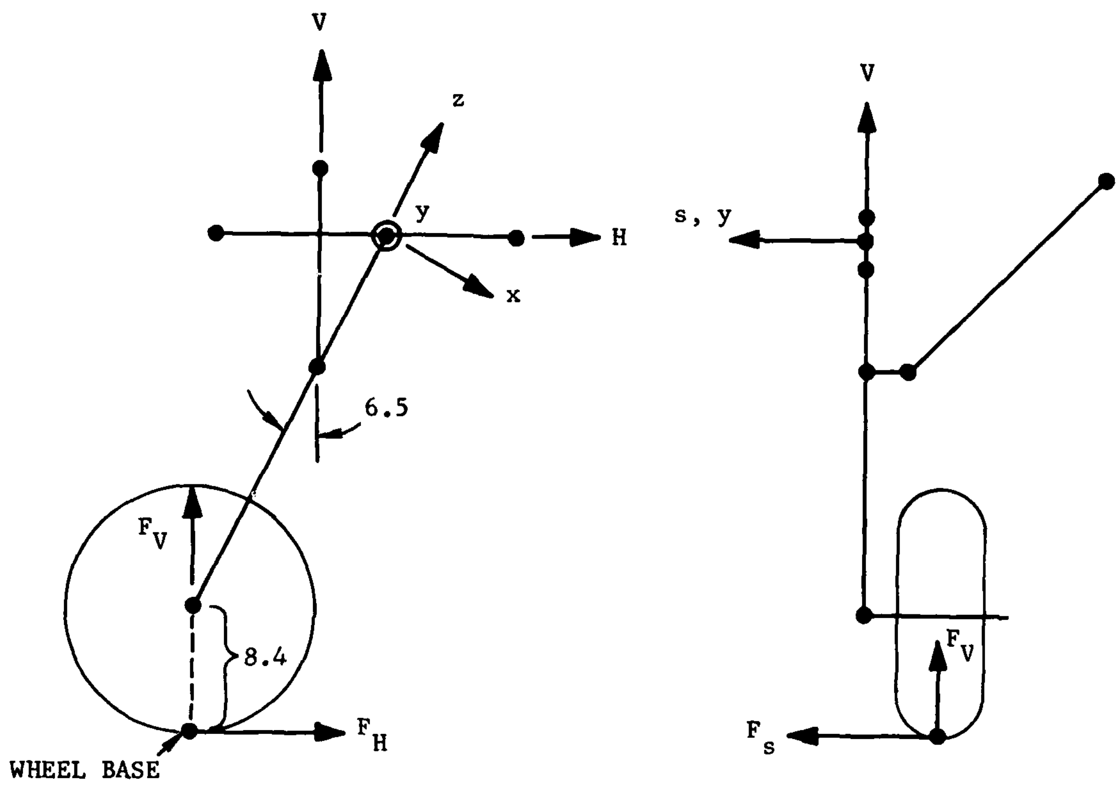


Figure V.2. Wheel Load Vectors Whose Values are Listed in Table V.3

Sketch V-3

TABLE V.3

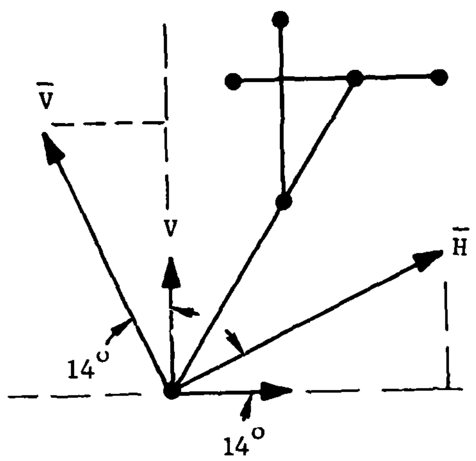
LIMIT LOADS ON 14,000 #A-37B AT WHEEL[+]

Condition	F_H (pounds)	F_s (pounds)	F_V (pounds)
1A	-2,582	0	10,326
1B	5,401	0	4,541
1C	-5,550	0	8,489
2A*	-5,296	0	9,946
2C*	-6,247	0	6,290
3A	0	-4,130	5,163
3B	0	3,098	5,163
4A	5,600	0	7,000
5A	-5,600	0	7,000
6A	0	-3,844	7,688
7	0	0	12,790

* See Figure V.4

\+ Reference 6

Sketch V-4



$$H = -\bar{V} \sin 14^\circ + \bar{H} \cos 14^\circ$$
$$V = \bar{V} \cos 14^\circ + \bar{H} \sin 14^\circ$$

CONDITION	$\bar{H}$	$\bar{V}$
2A	-2733	10,932
2C	-4540	7,615

CONDITION	H	V
2A	-5296	9946
2C	-6247	6290

Figure V.4. Calculations for Tail-Down Condition

Sketch V-5

The objective of the applied loads analysis is to transfer the loads in the H,S,V system at the wheel base to the near end of the axle in the x,y,z system. This point on the axle is the centroid of the tire. The reason for doing this transformation and rotation allows for a simpler loads analysis on the rest of the gear.

The transformation and rotation is achieved as shown in Figures V.5 and V.6 below.

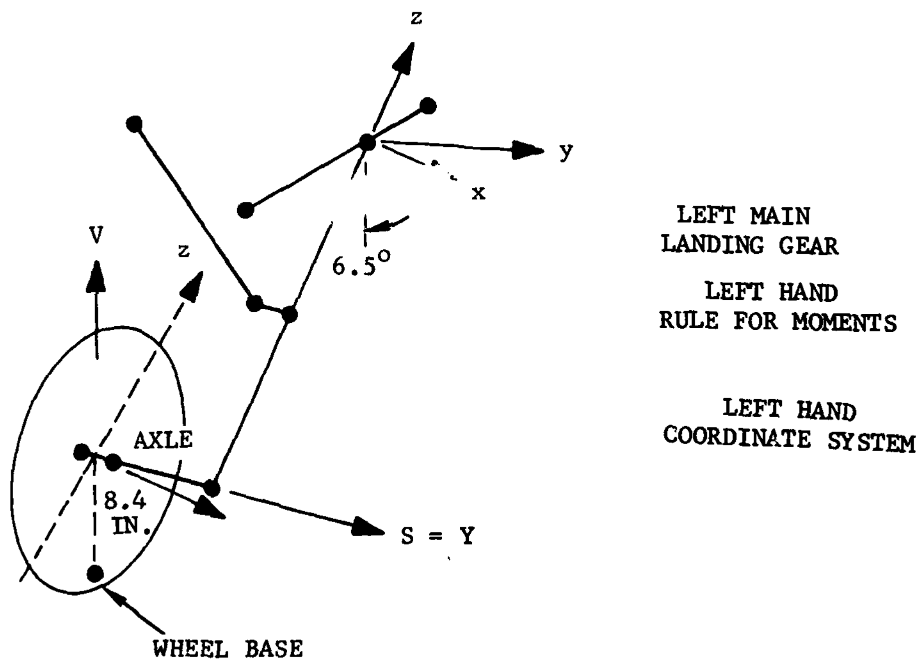


Figure V.5. Over-all View

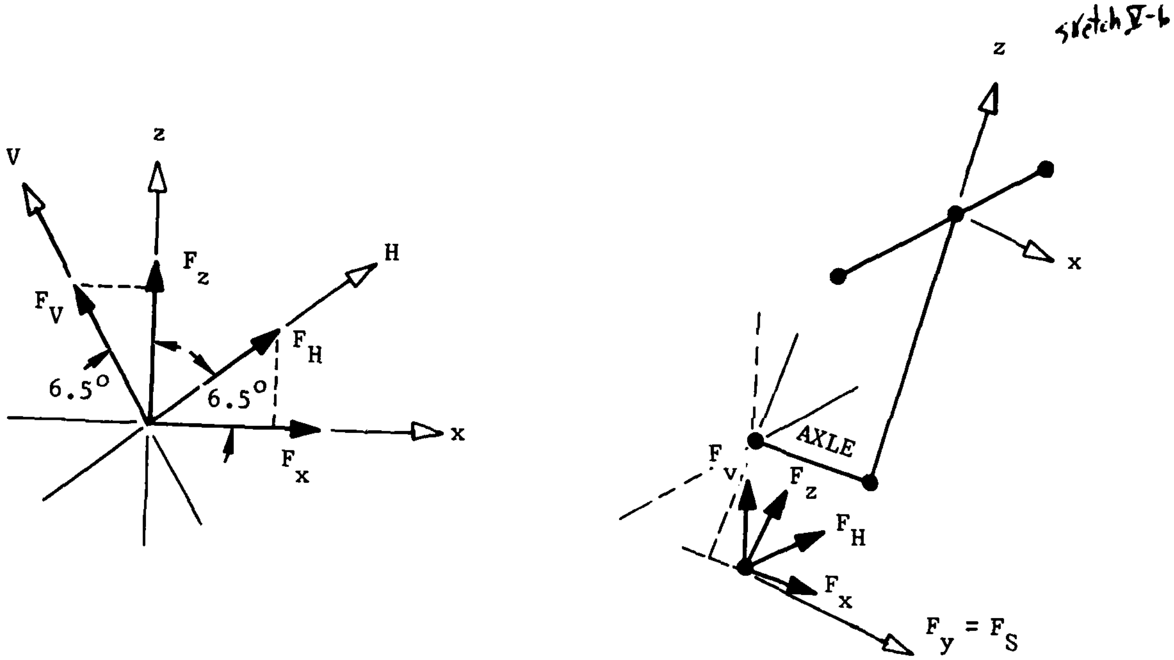


Figure V.6. Rotating Forces at Wheel Base

$$F_x = F_H \cos 6.5^\circ - F_V \sin 6.5^\circ$$

$$F_y = F_s$$

$$F_z = F_H \sin 6.5^\circ + F_V \cos 6.5^\circ$$

F_x, F_y, F_z will also be the same forces at the axle.

Next, moments about the x, y, and z axes can be easily found from the F_x, F_y, and F_z loads and are calculated at the axle (see Figure V.7).

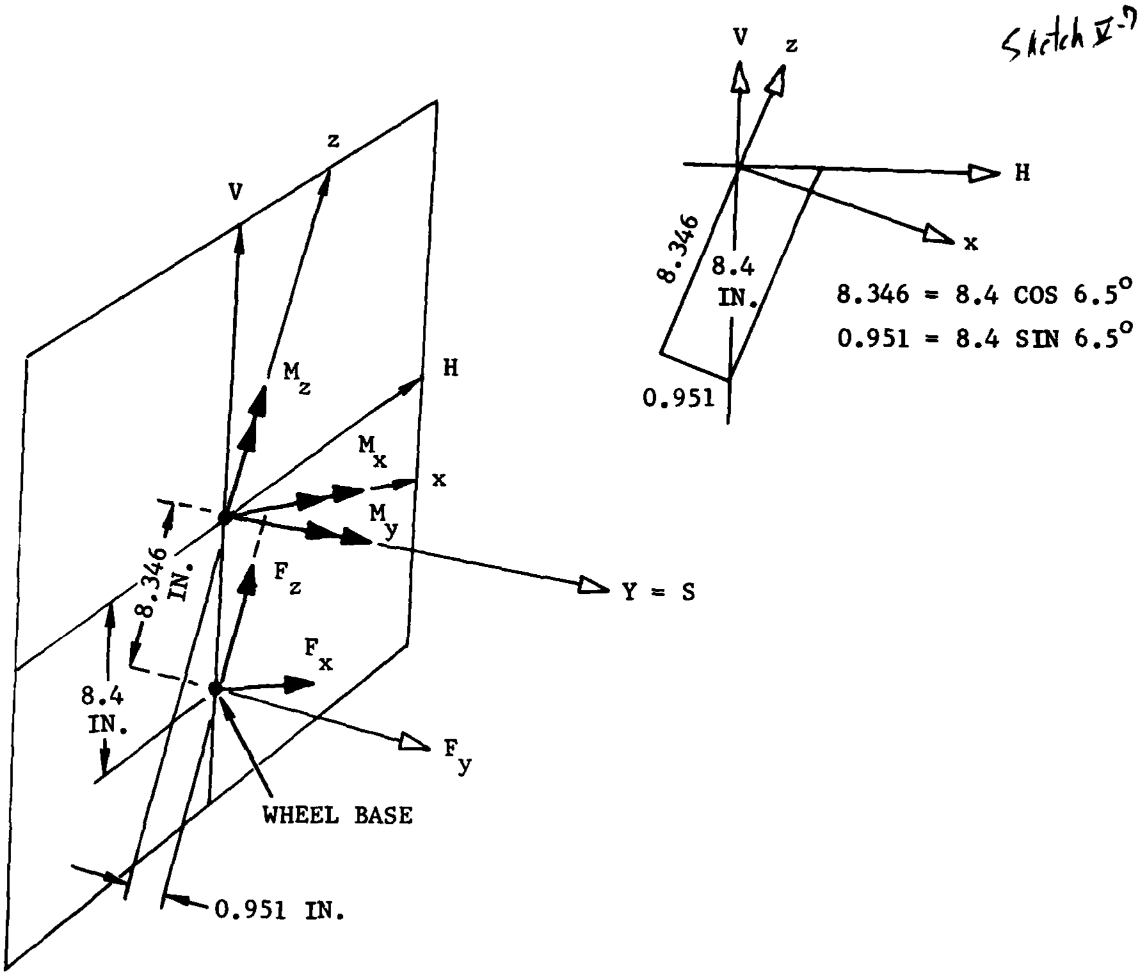


Figure V.7

Solutions of moments about the x, y, z axes translated to the end of the axle, due to loads F_x, F_y, F_z at the wheel base, are given below.

$$M_x = 8.346\ F_y$$

$$M_y = -8.346\ F_x - .951\ F_z{}^{*}$$

$$M_z = ..951\ F_y$$

---

*$M_y = 0$ for nonbraking conditions. That is, $M_y \neq 0$ for cases 4A and 5A only.

sketch V-8

Tables V.8 and V.9 list the limit and ultimate applied loads at the axle. The ultimate loads are 1.5 x the limit loads.

TABLE V.8

LIMIT LOADS AT THE AXLE END

	No.	F_x	F_y	F_z	M_x	M_y	M_z
1A	1	-3735	0	9967	0	0	0
1B	2	4853	0	5124	0	0	0
1C	3	-6476	0	7806	0	0	0
2A	4	-6388	0	9283	0	0	0
2C	5	-6919	0	5542	0	0	0
3A	6	-585	-4130	5130	-34469	0	-3928
3B	7	-585	3098	5130	25856	0	2947
4A	8	4771	0	7590	0	-47037	0
5A	9	-6357	0	6322	0	47043	0
6A	10	-871	-3844	7639	-32083	0	-3656
7	11	* 0	0	12708	0	0	0

*Upon calculation = -1448. However, for taxi conditions the inertia of the tire is neglected.

TABLE V.9

Sketch V-9

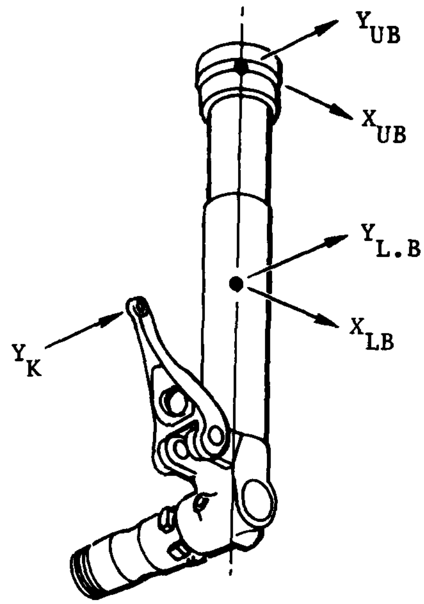
ULTIMATE LOADS AT THE AXLE END
(= 1.5 x LIMIT)

	No.	F_x	F_y	F_z	M_x	M_y	M_z
1A	1	-5603	0	14951	0	0	0
1B	2	7280	0	7686	0	0	0
1C	3	-9714	0	11709	0	0	0
2A	4	-9582	0	13925	0	0	0
2C	5	-10379	0	8313	0	0	0
3A	6	-878	-6195	7695	-51704	0	-5892
3B	7	-878	4647	7695	38784	0	4421
4A	8	7157	0	11385	0	-70556	0
5A	9	-9536	0	9483	0	70565	0
6A	10	-1307	-5766	11459	-48125	0	-5484
7	11	0	0	19062	0	0	0

V.B. Free Body Loads

The free body loads for the outer and inner assemblies have been adopted from Reference 4 and are summarized in Figures V.10 and V12 and Tables V.11 and V.13. Corrections for conditions 3A and 3B have been made, and the slight shift in side brace position with respect to the outer cylinder has been neglected. The loads given do account for a 7.5-inch axle length.

SHdthV-10



X_{UB} AND Y_{UB} RELATE TO THE UPPER BEARING REACTION WITH THE I.D. OF THE OUTER CYLINDER.

X_{LB} AND Y_{LB} RELATE TO THE LOWER BEARING REACTION WITH THE I.D. OF THE OUTER CYLINDER.

Figure V.10. Inner Assembly Load Definition

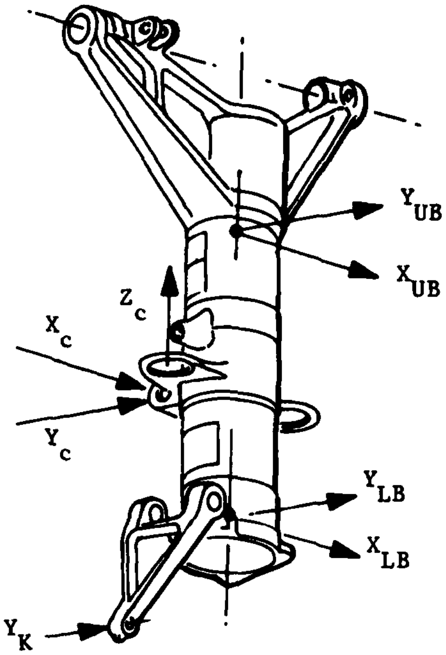
TABLE V.11

INNER ASSEMBLY APPLIED LOADS*

Cond.	X_{UB}	Y_{UB}	X_{LB}	Y_{LB}	Y_K
1A	-3900	-10100	9500	15300	-5200
1B	4800	-2900	-12100	-3900	6800
1C	-6400	-9100	16200	18200	-9100
2A	-6400	-10400	16000	19400	-9000
2C	-4500	-7200	14900	17000	-9700
3A	-500	-13300	1400	21000	-1600
3B	-500	1800	1400	-6100	-300
4A	7500	-4800	-14700	-1300	6100
5A	-8300	-5800	17900	14000	-8200
6A	-500	-11600	1800	19100	-1700
7+	0	0	0	0	0

*Loads acting <u>ON</u>, not <u>BY</u>, the assembly.

+2G taxi load acts through fluid pressure.



sketch V-11

UB AND LB REFER TO THE UPPER AND LOWER BEARING LOCATIONS ON THE O.D. OF THE PISTON.

X_c, Y_c, AND Z_c ARE SIDE BRACE REACTIONS.

Figure V.12. Outer Assembly Load Definition

TABLE V.13

OUTER ASSEMBLY LOADS*

Cond	X_{UB}	Y_{UB}	X_c	Y_c	Z_c	X_{LB}	Y_{LB}	Y_K
1A	3900	10000	1100	7500	-9300	-9500	-15300	5200
1B	-4800	2900	500	3300	-4100	12100	3900	-6800
1C	6400	9100	900	6200	-7600	-16200	-18200	9100
2A	6400	10400	1000	-7230	-8900	-1600	-19400	9000
2C	4500	7200	600	4600	-5600	-14900	-17000	9700
3A	500	13300	2600	18300	-22600	-1400	-21000	1600
3B	500	-1800	-1000	-7300	9000	-1400	6100	300
4A	-7500	4800	700	5100	-6300	14700	1300	-6100
5A	8300	5800	700	5100	-6300	-17900	-14000	8200
6A	500	11600	2600	18400	-22700	-1800	-19100	1700
7+	0	0	0	0	0	0	0	0

*Loads acting <u>ON</u>, not <u>BY</u>, the assembly.

+2G Taxi load acts through fluid pressure to trunnion.

V.C. Reaction Loads

Sketch V-12

Free body loads not shown in Figure 12 of the previous section are the reaction loads between the aircraft frame and the trunnion of the landing gear. Because these loads are critical to the trunnion design, an indeterminate analysis using the finite-element method was performed. Rigid beams were used to model portions of the gear as shown in Figure V.14 below.

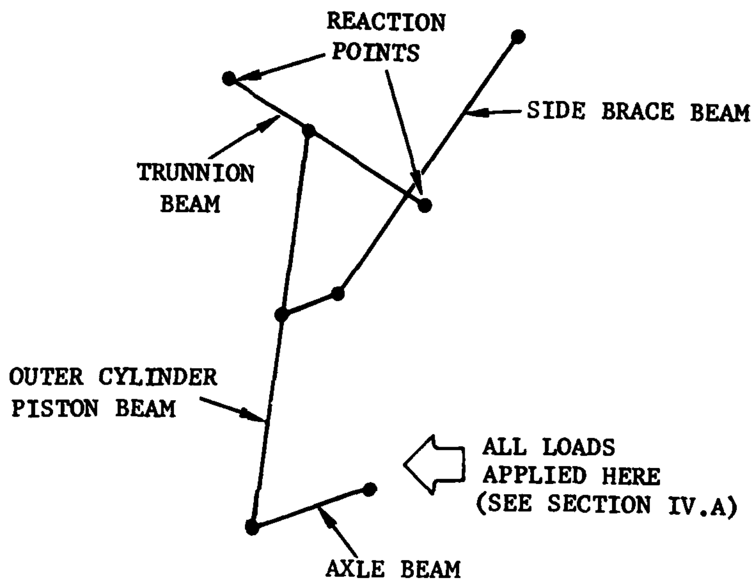
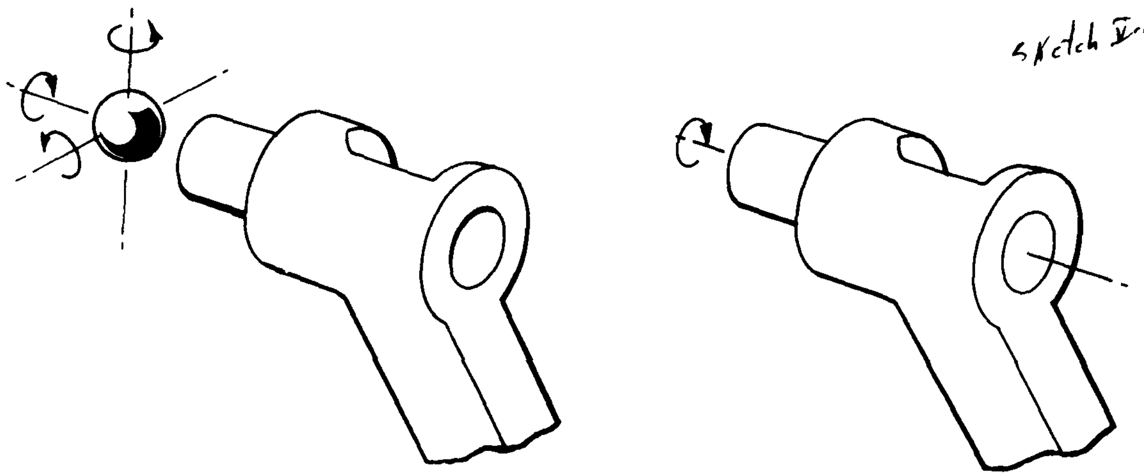


Figure V.14. Finite-Element Beam Model of Landing Gear.

In Figure V.14, the reaction points are the forward and aft lug locations on the trunnion. This model allows for easy and quick calculations of all lug loads for all loading (landing and static) conditions. Also, two boundary conditions were looked at, at the reaction points. One is a ball joint and the other a single pin joint (see Figure V.15 below).

Sketch V-13



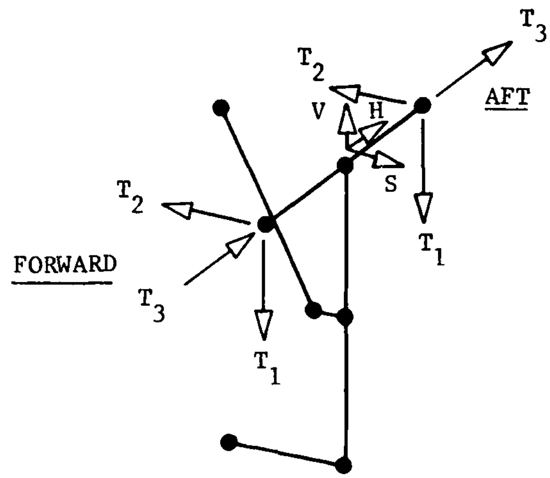
BALL JOINT (NO MOMENTS AT REACTION POINTS)

SINGLE PIN JOINT (2 MOMENTS AT EACH REACTION POINT)

Figure V.15. Boundary Conditions at Reaction Points

The two boundary conditions at the reaction points were analyzed to two extreme load conditions on the trunnion. The ball joint creates a conservative load state at the base of the trunnion arms (at the junction near the outer cylinder), and a single pin joint creates a conservative load state at the lugs. In reality, the load state is somewhere between these two boundary conditions because of the "slop" or looseness between the lugs and the frame of the aircraft. Both conditions are investigated in the chapter on trunnion design and analysis.

Figures V.16 and V.18 and Tables V.17 and V.19 show and list the loads, respectively, for the ball joint boundary condition in both the H,S,V and x,y,z systems. Figures V.20 and V.22 and Tables V.21 and V.23 show and list, respectively, the single pin joint boundary conditions in both the H,S,V and x,y,z systems.



Sketch V-14

Figure V.16. Trunnion Reaction Loads in H,S,V System

TABLE V.17

TRUNNION REACTION LOADS IN H,S,V SYSTEM FOR BALL JOINTS

	Forward			Aft		
Case	T_1 Lbs	T_2 Lbs	T_3 Lbs	T_1 Lbs	T_2 Lbs	T_3 Lbs
1A	13,066	5970	3866	-6,958	1547	0
1B	-14,404	-2965	0	17,088	6267	-8124
1C	21,255	7816	8313	-16,254	-1661	0
2A	21,259	8146	7965	-15,403	-938	0
2C	22,379	7630	9393	-18,675	-3071	0
3A	-6,308	5066	17	-8,418	6657	0
3B	9,354	-495	26	7,135	-1771	0
4A	-17,884	-2251	0	22,017	7338	-8444
5A	24,253	7309	8363	-20,120	-2222	0
6A	-4,196	5432	-14	-6,732	6709	0
7	1,851	3394	-2173	5,648	5836	0

Sketch V-15

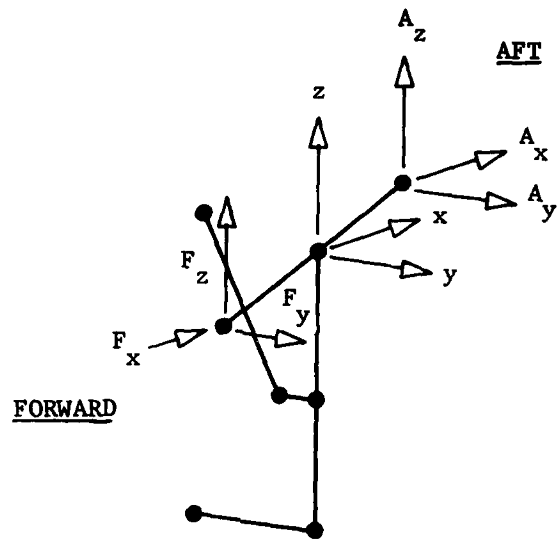
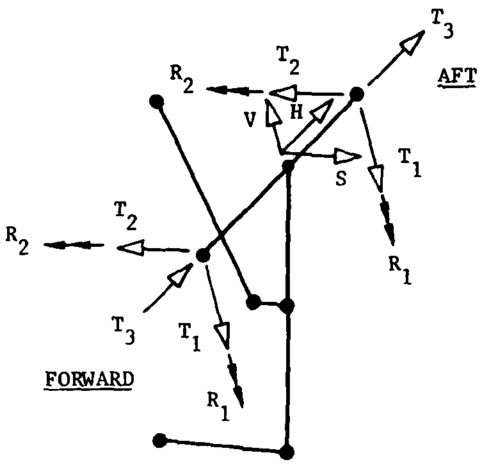


Figure V.18. Trunnion Reaction Loads

TABLE V.19

TRUNNION REACTION LOADS IN THE x,y,z SYSTEM FOR BALL JOINTS

Cond	F_x Lbs	F_y Lbs	F_z Lbs	A_x Lbs	A_y Lbs	A_z Lbs
1A	5,320	-5,970	-12,544	-787	-1,547	6,913
1B	-1,630	2,965	14,311	-6,137	-6,267	-17,897
1C	10,665	-7,816	-20,177	-1,840	16,612	16,149
2A	10,320	-8,146	-20,217	-1,743	938	15,303
2C	11,865	-7,630	-21,171	-2,114	3,071	18,553
3A	-697	-5,066	6,269	-953	-6,657	8,363
3B	1,084	495	-9,290	807	1,771	-7,089
4A	-2,024	2,251	17,769	-5,897	-7,338	-22,831
5A	11,054	-7,309	-23,150	-2,277	2,222	19,990
6A	-488	-5,432	4,167	-762	-6,709	6,688
-	-1,949	-3,394	-2,085	639	-5,836	-5,611



Sketch V-16

Figure V.20. Trunnion Reaction Loads

TABLE V.21

TRUNNION REACTION LOADS IN THE H,S,C SYSTEM FOR SINGLE PIN CONDITION

	Cond	T_1 Lbs	T_2 Lbs	T_3 Lbs	R_1 In./Lbs	R_2 In./Lbs
	1A	17,466	6,918	3,866	-21,992	52,458
	1B	-21,371	-5,017	0	13,867	-61,777
F	1C	29,522	9,887	8,313	-30,337	87,401
O	2A	29,336	10,125	7,965	-31,285	87,063
R	2C	31,435	9,977	9,393	-30,222	92,678
W	3A	-5,785	4,670	17	-16,426	-20,397
A	3B	9,781	-204	26	1,135	32,486
R	4A	-26,714	-4,389	0	11,610	-77,037
D	5A	34,040	9,395	8,363	-28,648	100,390
	6A	-3,504	5,103	-14	-17,791	-13,096
	7	983	2,819	-2,173	-10,427	4,658
	1A	-11,358	599	0	9,488	5,555
	1B	24,055	8,320	-8,124	13,190	-30,077
	1C	-24,521	-3,731	0	3,041	21,594
	2A	-23,480	-2,918	0	5,186	19,426
A	2C	-27,731	-5,418	0	-719	26,710
F	3A	-8,941	7,053	0	21,649	27,286
T	3B	6,708	-2,062	0	-4,968	-26,854
	4A	30,848	9,476	-8,443	16,579	-39,384
	5A	-29,907	-4,308	0	1,141	28,644
	6A	-7,334	7,038	0	22,123	21,033
	7	6,515	6,411	0	18,006	-16,093

Sketch V-17

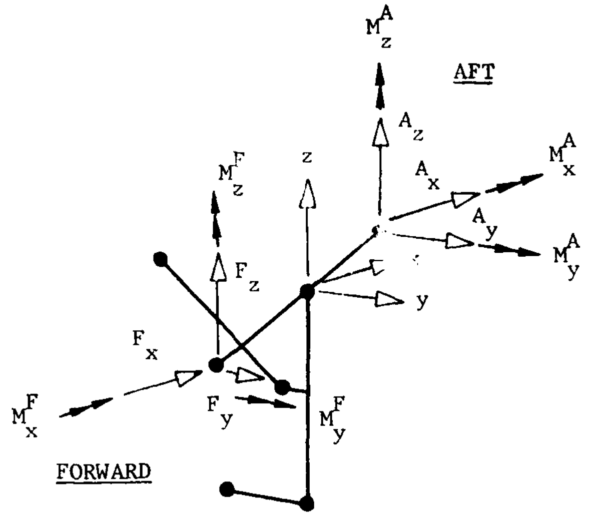


Figure V.22. Trunnion Reaction L[illegible]ds

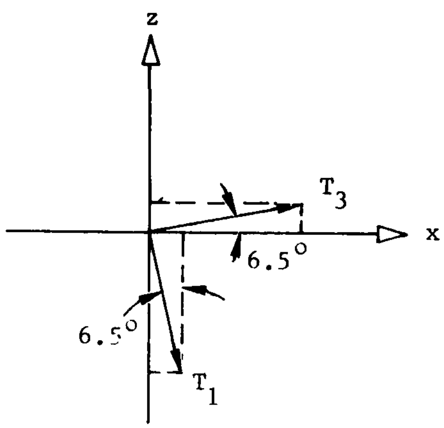
TABLE V.23

TRUNNION REACTION LOADS IN THE x,y,z SYSTEM 1[illegible]
SINGLE PIN CONDITION

	Cond	F_x Lbs	F_y Lbs	F_z Lbs	M^F_x In./Lbs	M^F_y In./Lbs	M^F_z In./Lbs
	1A	5,818	-6,918	-16, 16	2,489	52,458	-21,850
	1B	-2,419	5,017	21,233	-1,569	-61,777	13,777
F	1C	11,601	-9,887	-28,391	3,434	87,401	-30,141
O	2A	11,234	-10,125	-28,245	3,541	87,063	-31,083
R	2C	12,891	9,977	-30,187	3,421	92,678	-30,027
W	3A	-637	4,670	5,749	1,859	-20,397	-16,320
A	3B	1,133	204	-9,715	-128	32,486	1,127
R	4A	-3,024	4,389	26,542	-1,314	-77,037	11,535
D	5A	12,162	-9,395	-32,874	3,243	100,390	-28,463
	6A	-420	-5,103	3,569	2,013	-13,096	-17,676
	7	-2,047	-2,819	--1,222	1,180	4,658	-10,359
	Cond	**A_y Lbs**	**A_y Lbs**	**A_z Lbs**	**M^A_x In./Lbs**	**M^A_y In./Lbs**	**M^A_z In./Lbs**
	1A	-1,285	-599	11,284	-1,074	5,555	9,427
	1B	-5,348	-8,320	-24,820	-1,493	-30,077	13,105
	1C	-2,775	3,731	24,363	-344	21,594	3,021
	2A	-2,658	3,918	23,32[illegible]	-587	19,426	5,152
A	2C	-3,139	5,418	27,552	81	26,710	-714
F	3A	-1,012	-7,053	-8,883	-2,450	27,286	21,509
T	3[illegible]	759	2,062	-6,664	562	-26,854	-4,936
	[illegible]	-4,896	-9,476	-31,605	-1,876	-39,384	16,472
	5A	-3,385	4,308	29,714	-129	28,644	1,133
	6A	-830	-7,038	7,286	-2,504	21,033	21,980
	7	737	-6,411	-6,473	-2,038	-16,093	17,890

Sketch V-18

The loads given from the computer output were the T_j, R_j loads. Transformations to get A_j F_j, M^F_j, M^A_j were made by calculations using the following equations shown below.



$$F_y = -T_2^{fwd}$$

$$A_y = -T_2^{aft}$$

$$F_x = T_3^{fwd} \cos 6.5 + T_1^{fwd} \sin 6.5$$

$$A_x = T_3^{aft} \cos 6.5 + T_1 \sin 6.5$$

$$F_z = T_3^{fwd} \sin 6.5 - T_1^{fwd} \cos 6.5$$

$$A_2 = T_3^{aft} \sin 6.5 - T_1^{aft} \cos 6.5$$

$$M^F{}_x = -R_1^{fwd} \sin 6.5$$

$$M^F{}_y = R_2^{fwd}$$

$$M^F{}_z = R_1^{fwd} \cos 6.5$$

$$M^A{}_x = -R_1^{aft} \sin 6.5$$

$$M^A{}_y = R_2^{aft}$$

$$M^A{}_z = R_1^{fwd} \cos 6.5$$

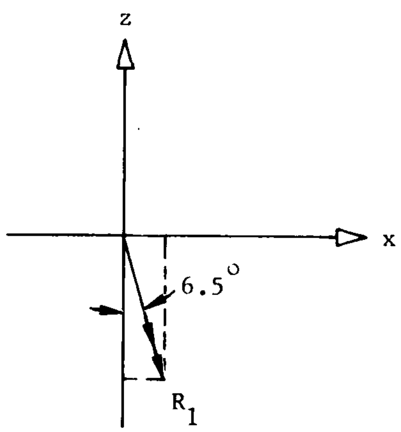
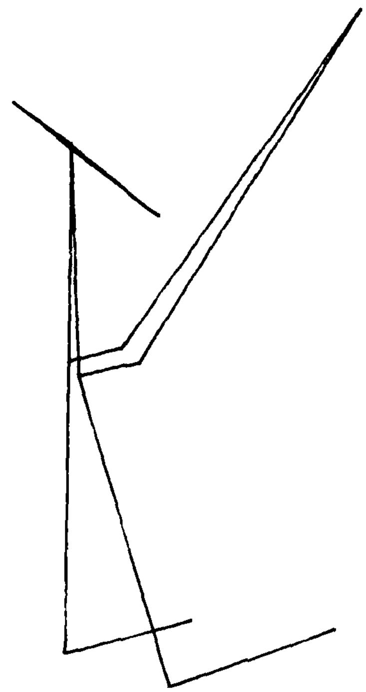


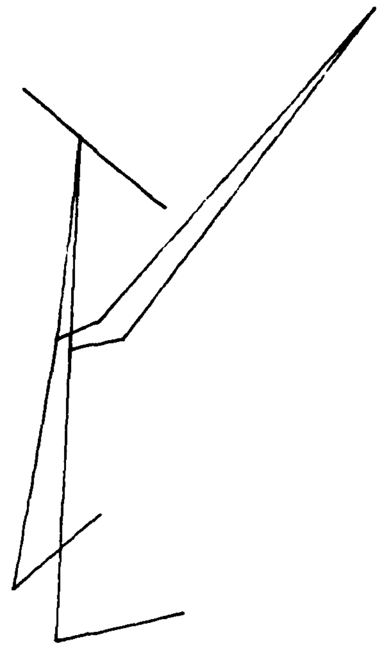
Figure V.26 shows the general computer-plotted, deflected shapes of the landing gear under the given load conditions.

Figure V.26

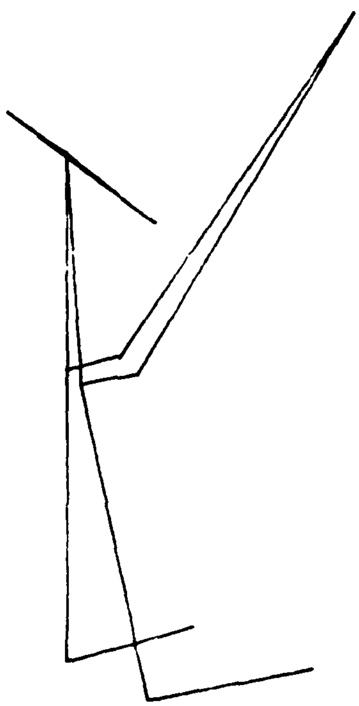
sketch IV-19



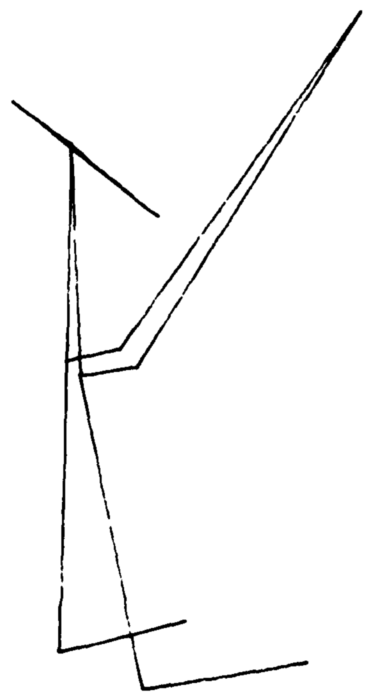
(a) LOAD CONDITION 1A



(b) LOAD CONDITION 1B



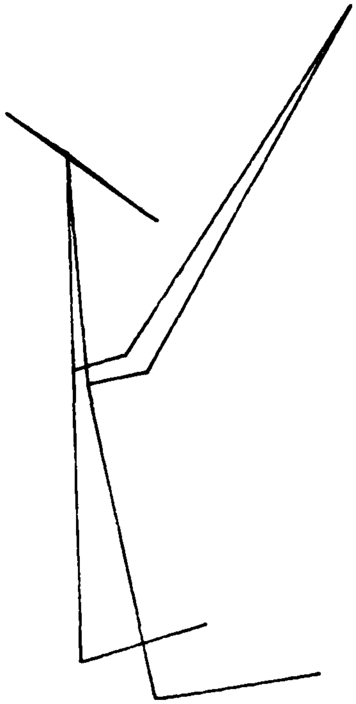
(c) LOAD CONDITION 1C



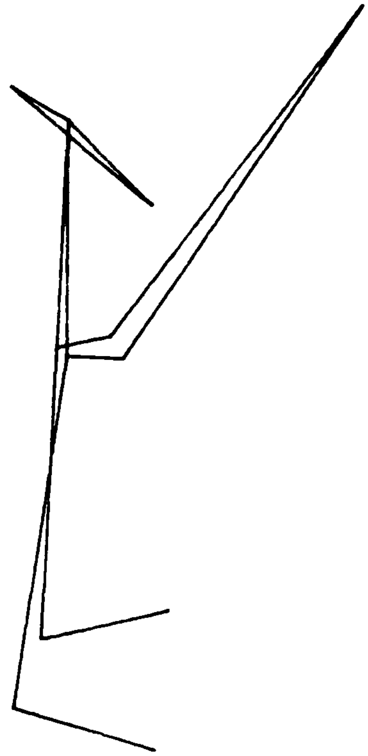
(d) LOAD CONDITION 2A

sketch V-20

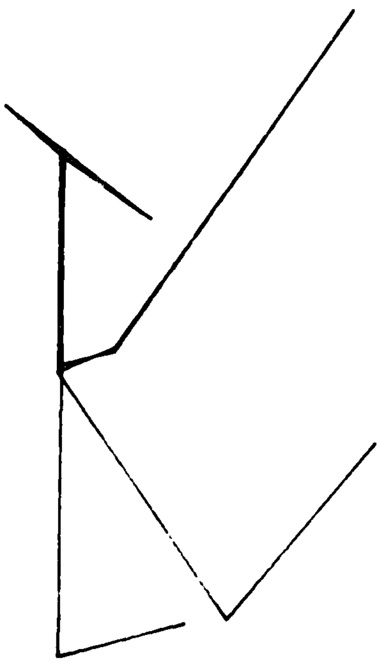
Figure V.26



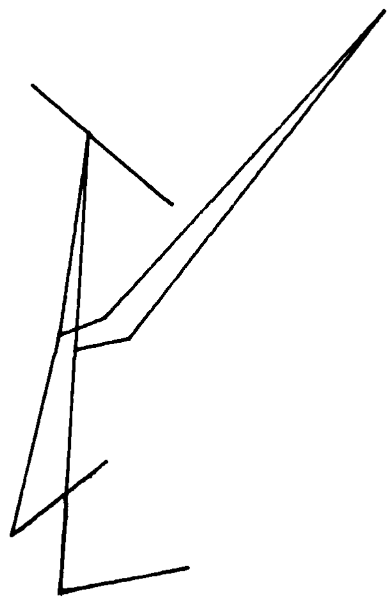
(e) LOAD CONDITION 2C



(f) LOAD CONDITION 3A

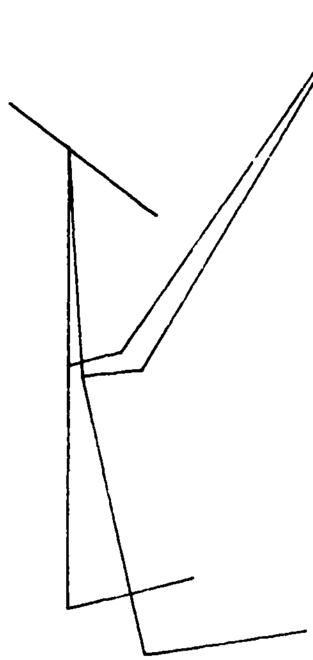


(g) LOAD CONDITION 3B

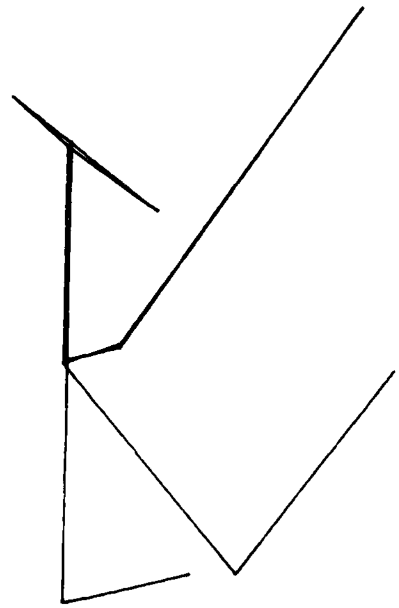


(h) LOAD CONDITION 4A

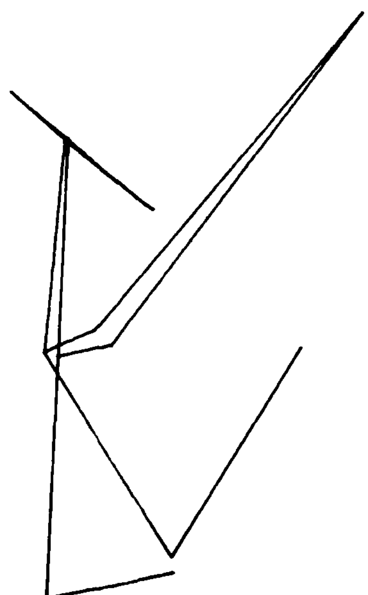
Sketch V-21



(i) LOAD CONDITION 5A



(j) LOAD CONDITION 6A



(k) LOAD CONDITION 7

SUckh V-22

REFERENCES

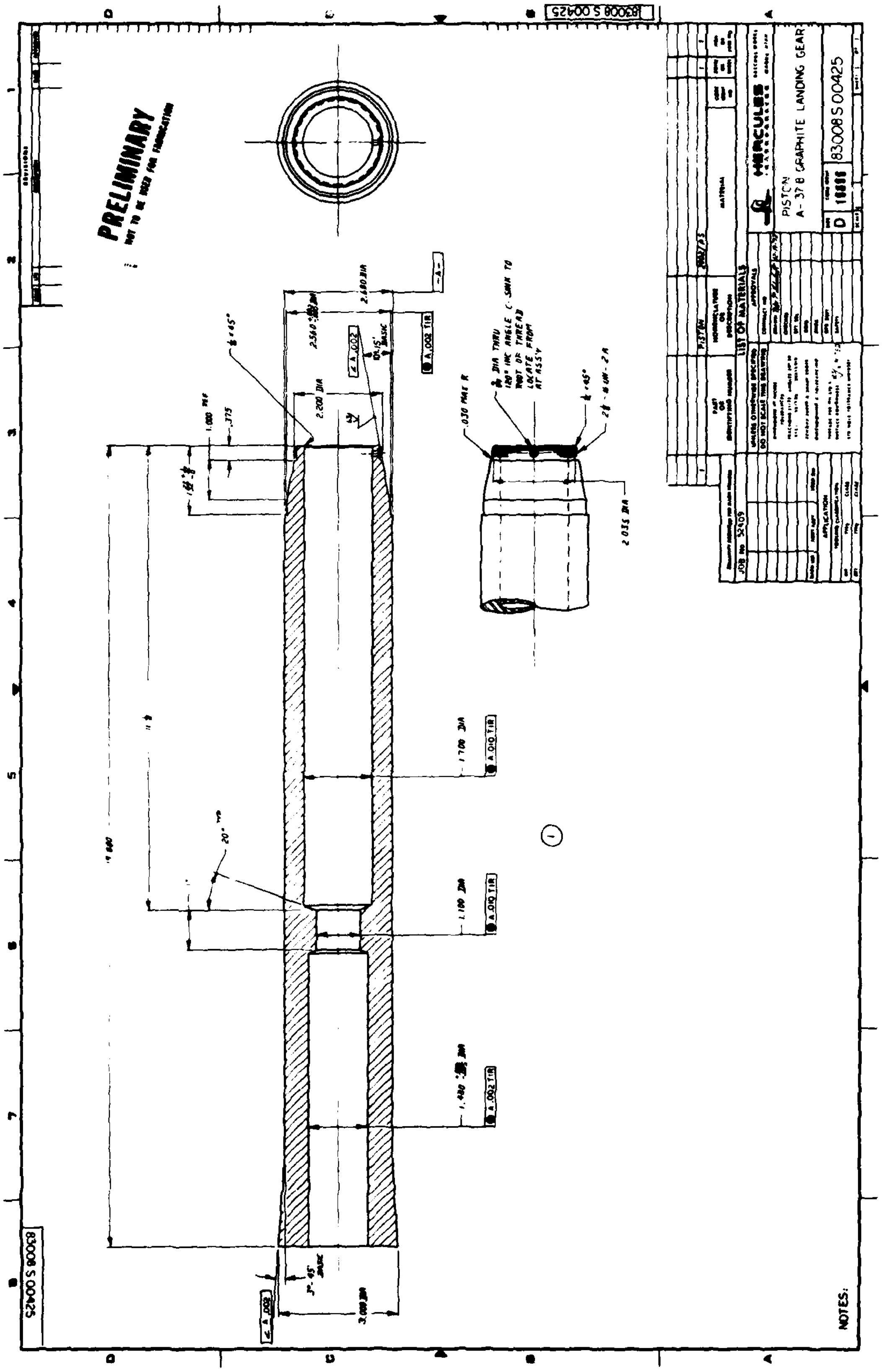
1. "Third Interim Report, Filament Composite Material Landing Gear Program," The Bending Corporation, Indiana, 14 December 1970.

2. "Landing Gear and Support Structure, Static Test," Cessna Aircraft Company, Wichita, Kansas, Report Number 318E-6704-081, Revision H, 16 September 1971.

APPENDIX A

PART VI

GRAPHITE COMPOSITE LANDING GEAR COMPONENT DRAWINGS



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A.092 TIR
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1.700 DIA
1.100 DIA
2.035 DIA
.030 MAX R
20°
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HERCULES
PISTON
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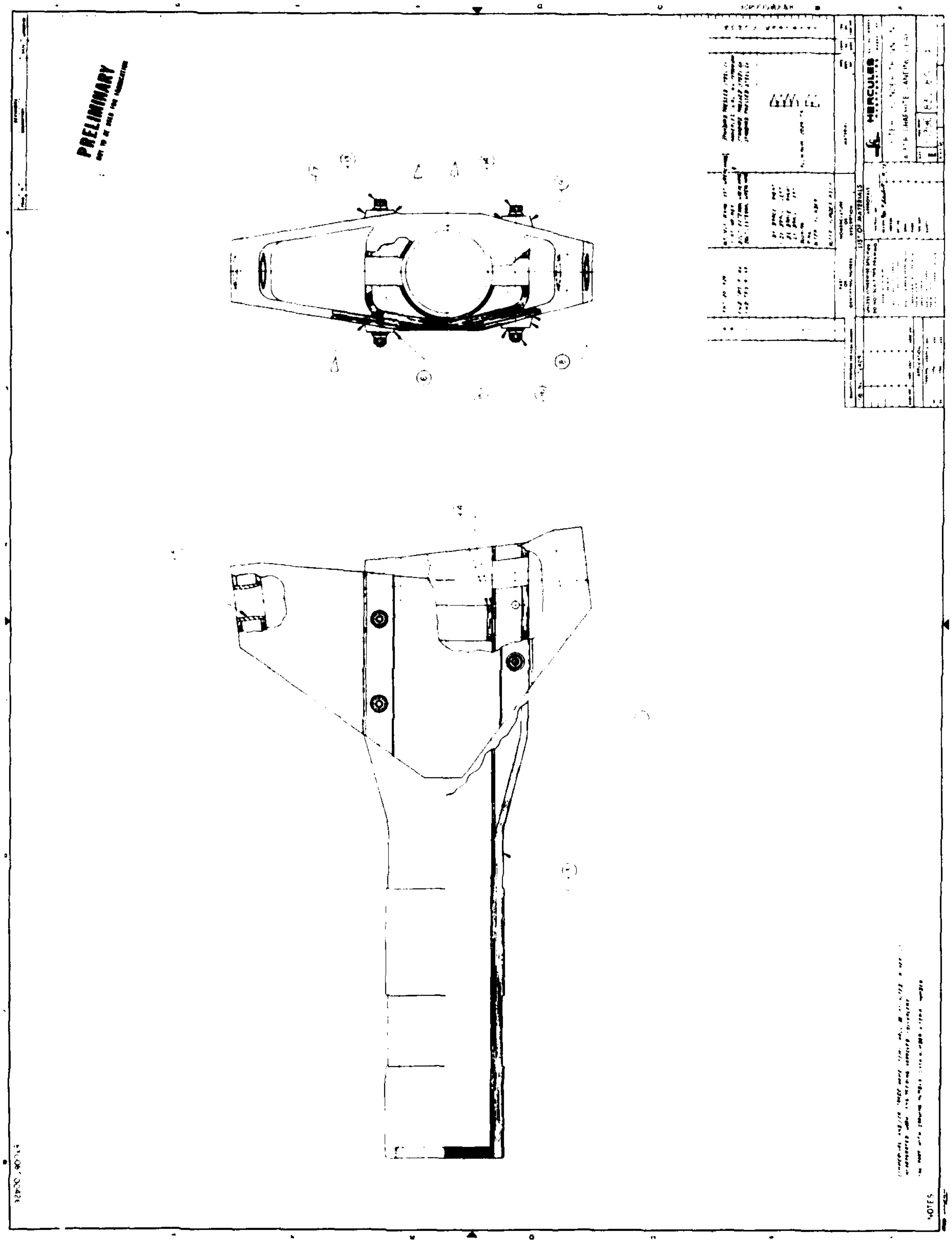
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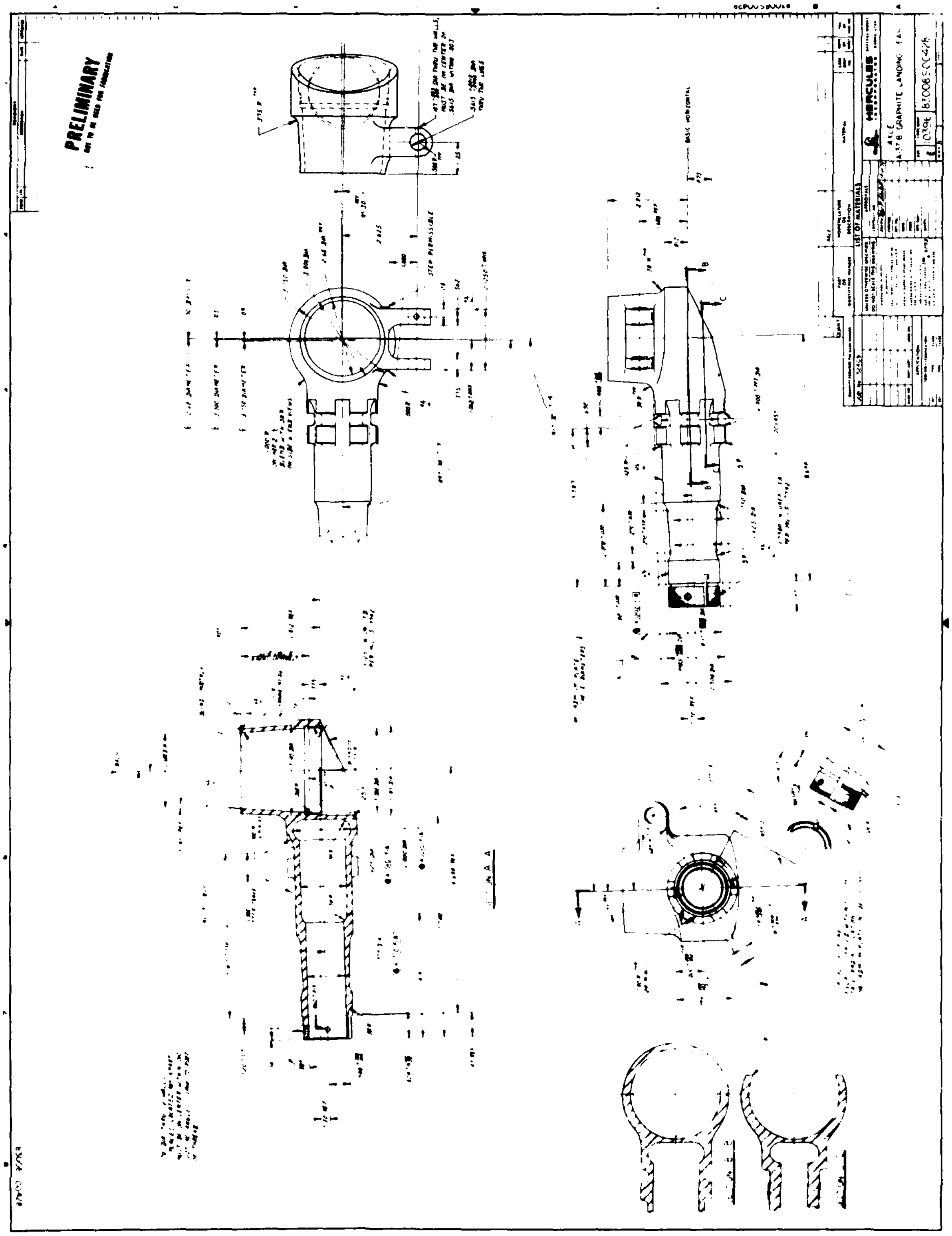
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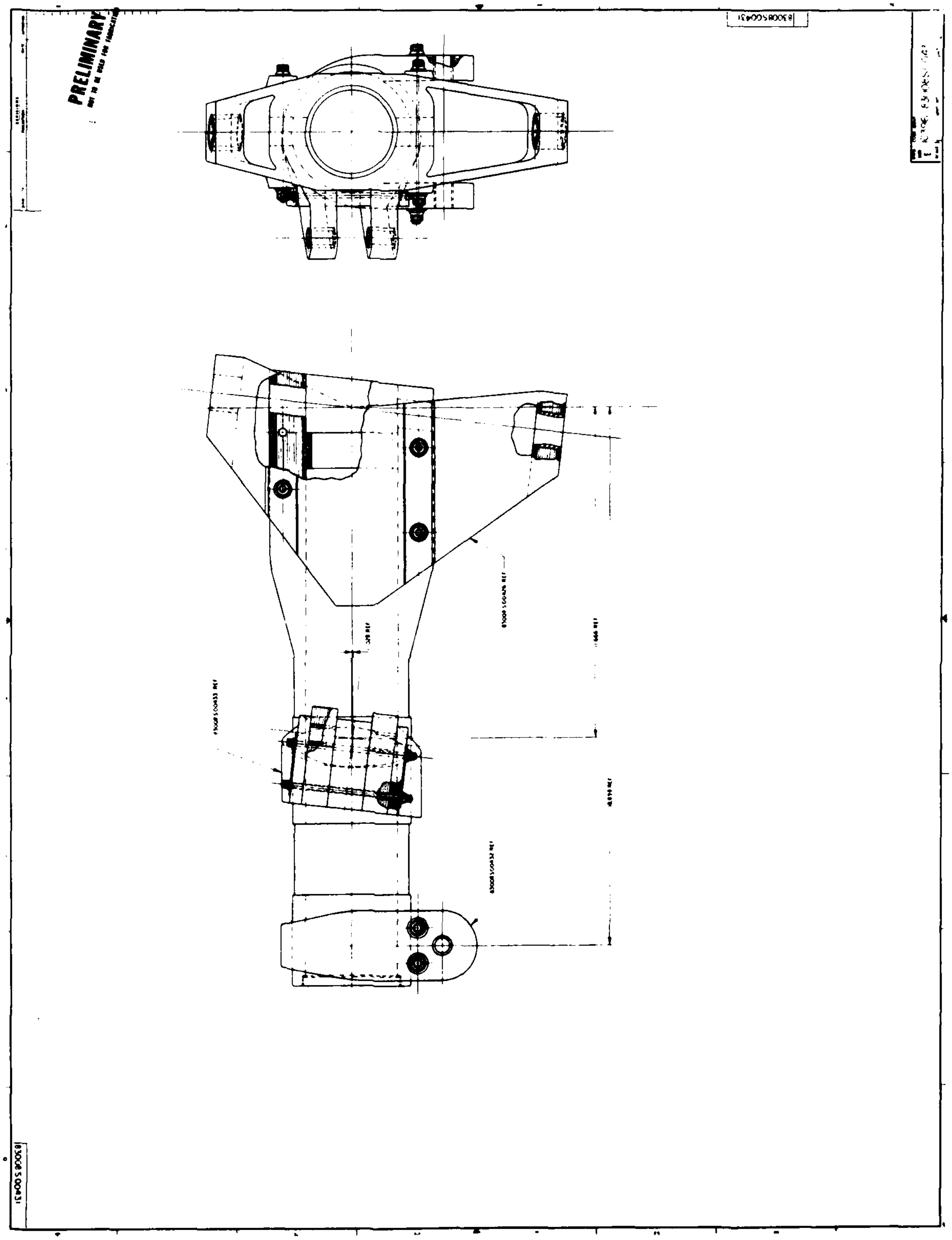
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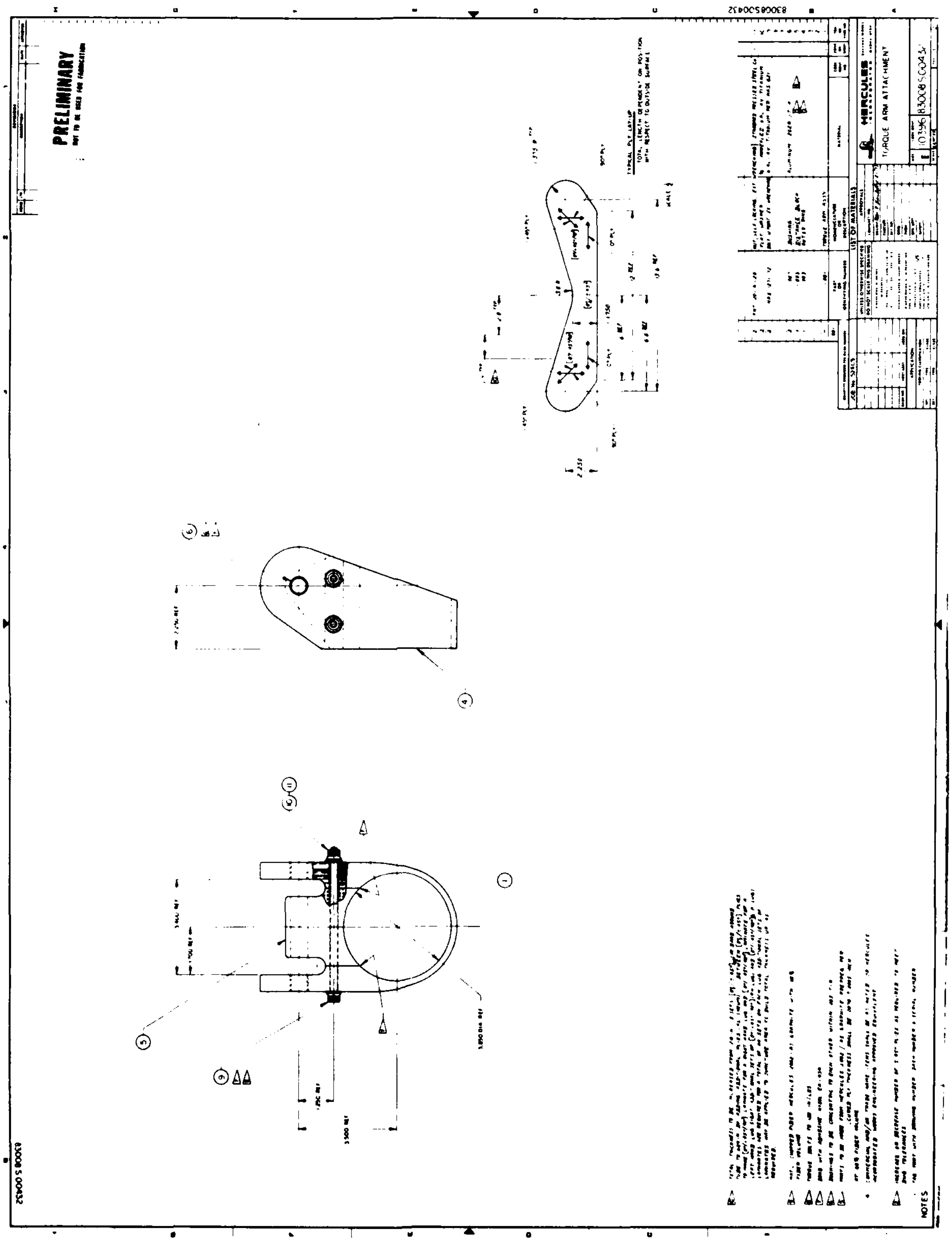
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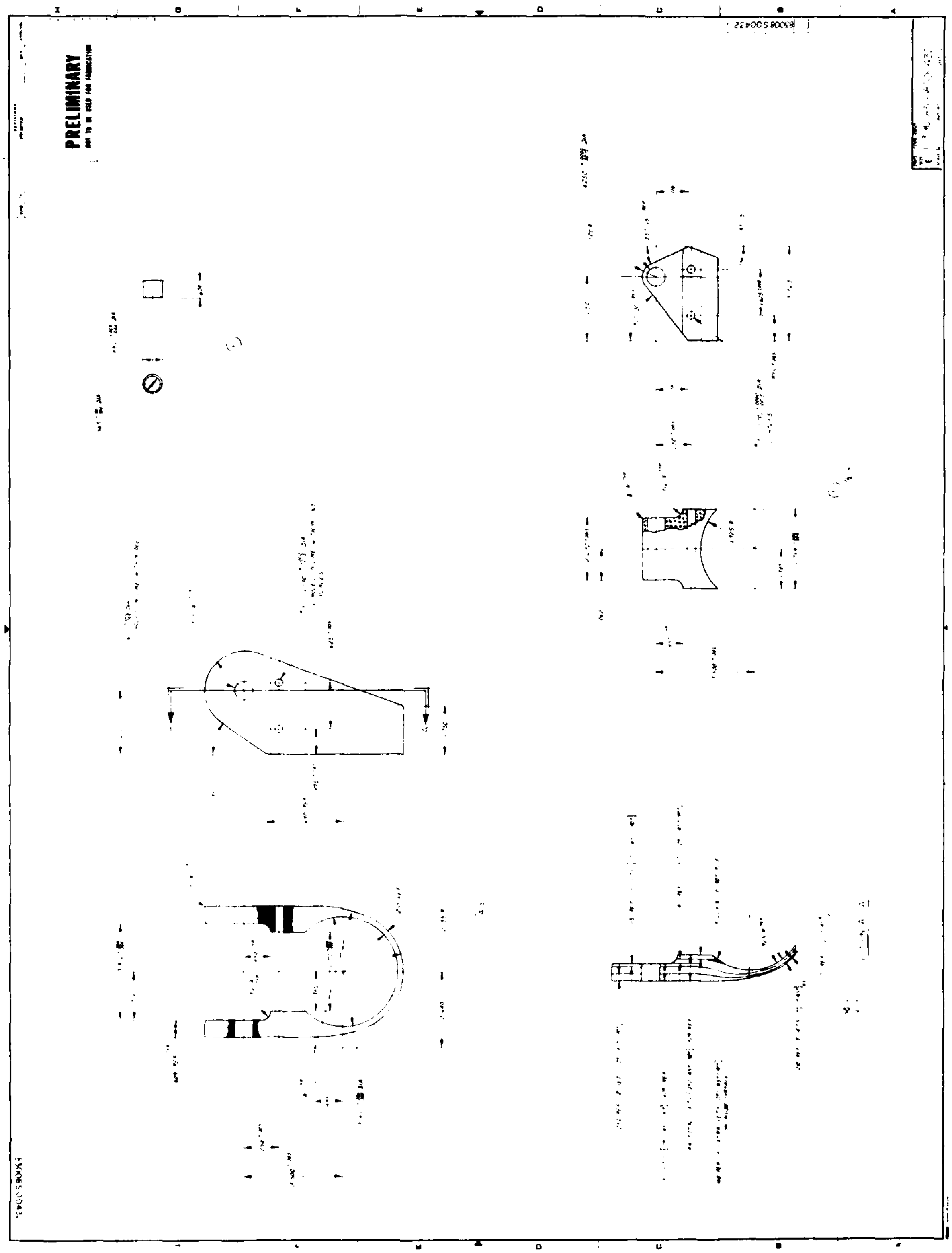
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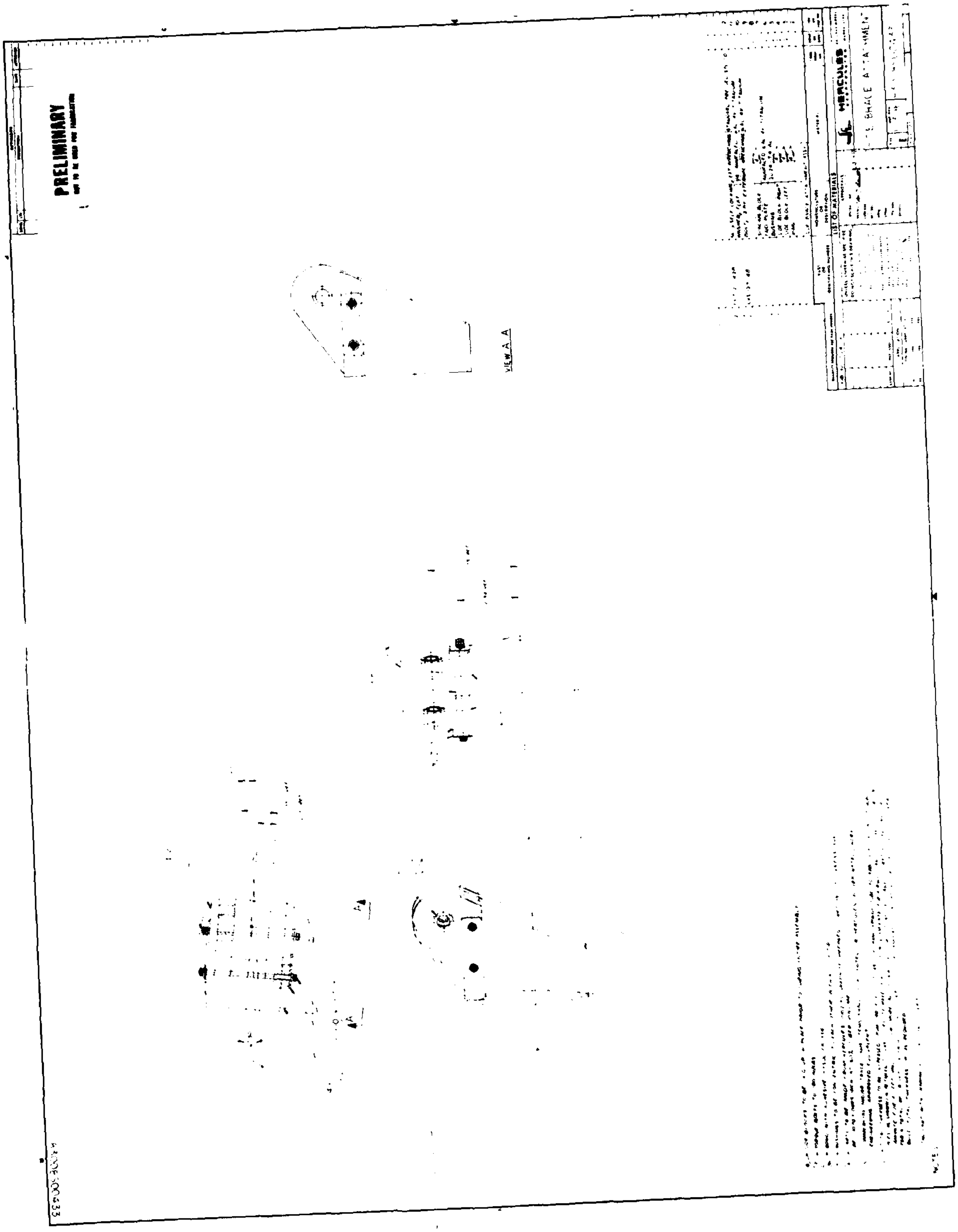
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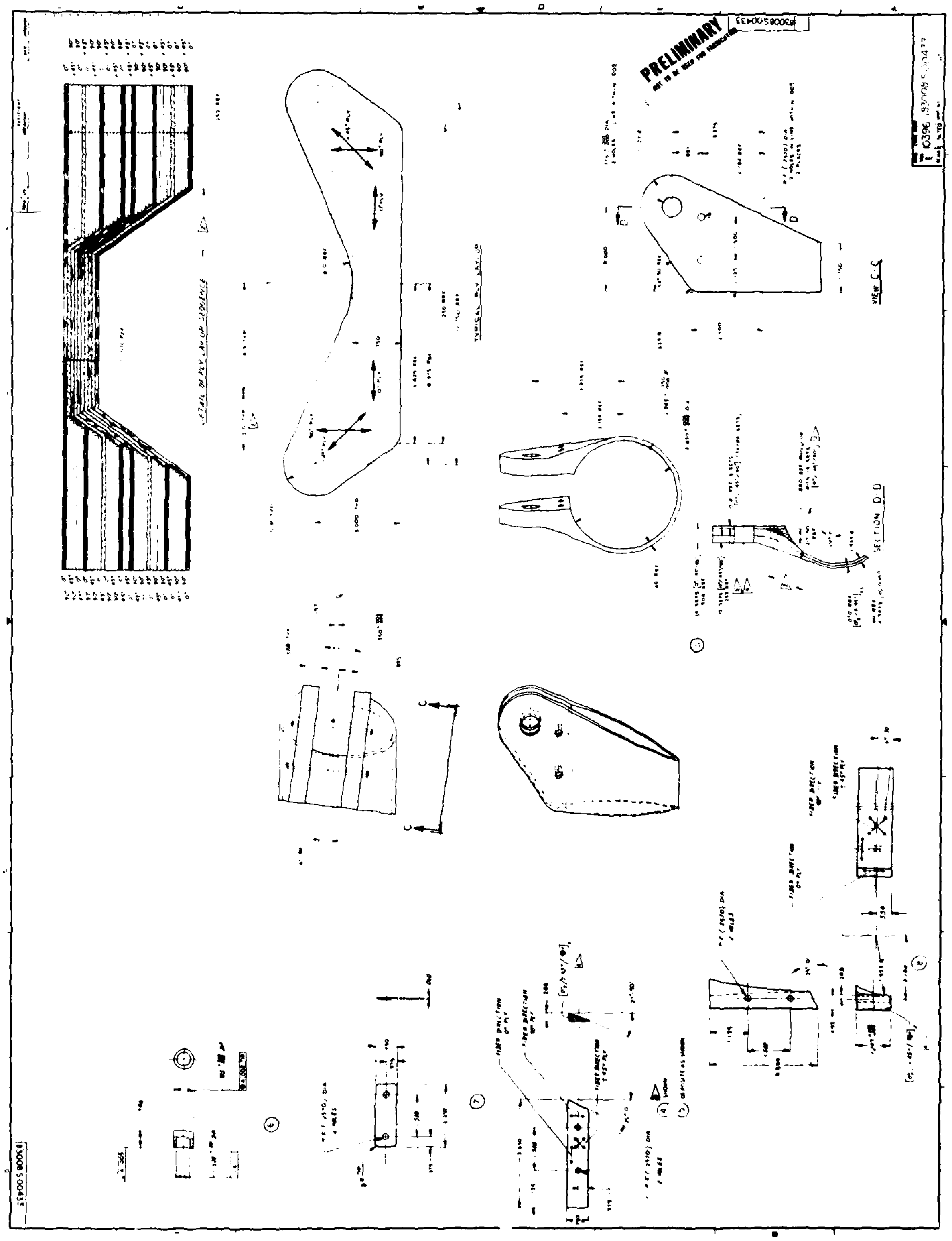
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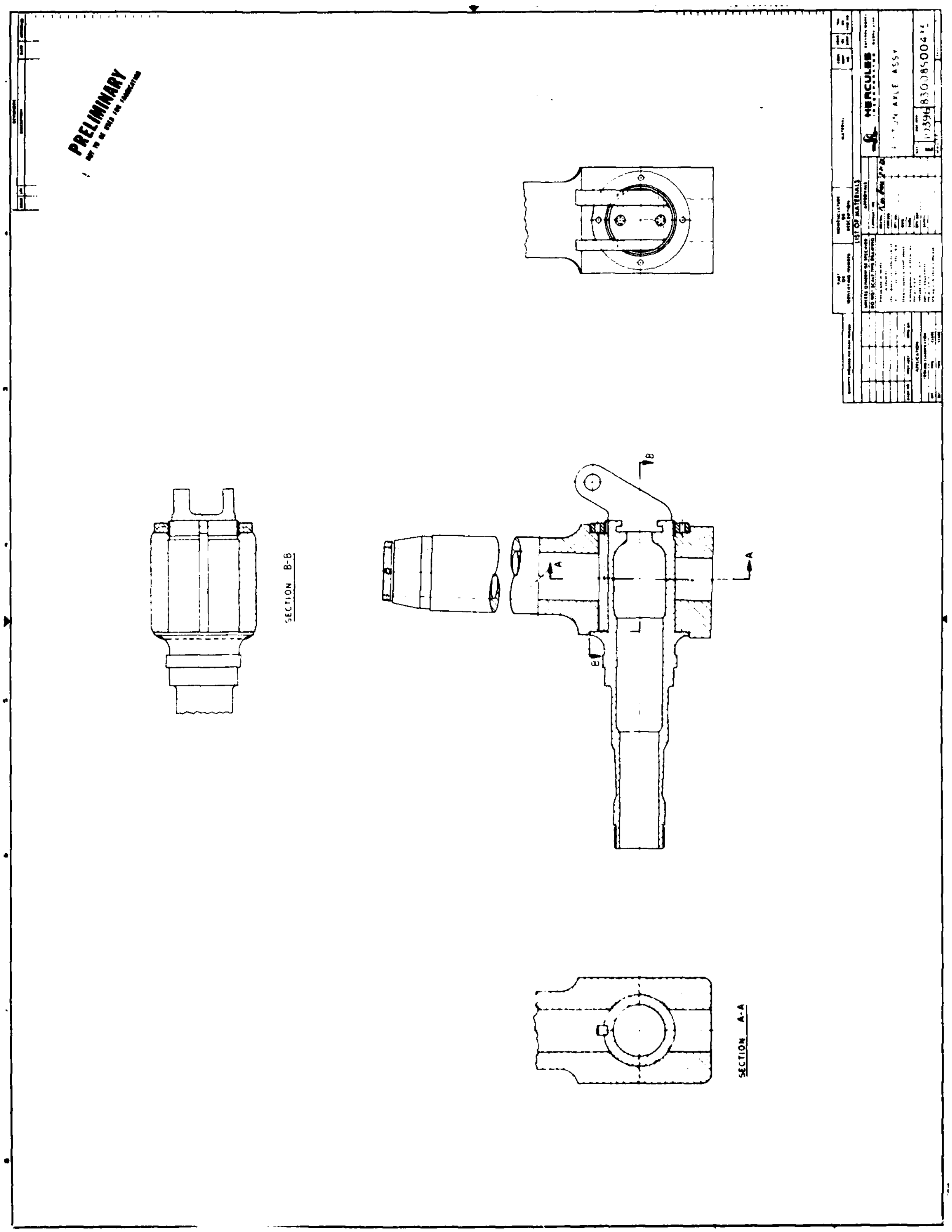
SECTION D-D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SECTION A-A
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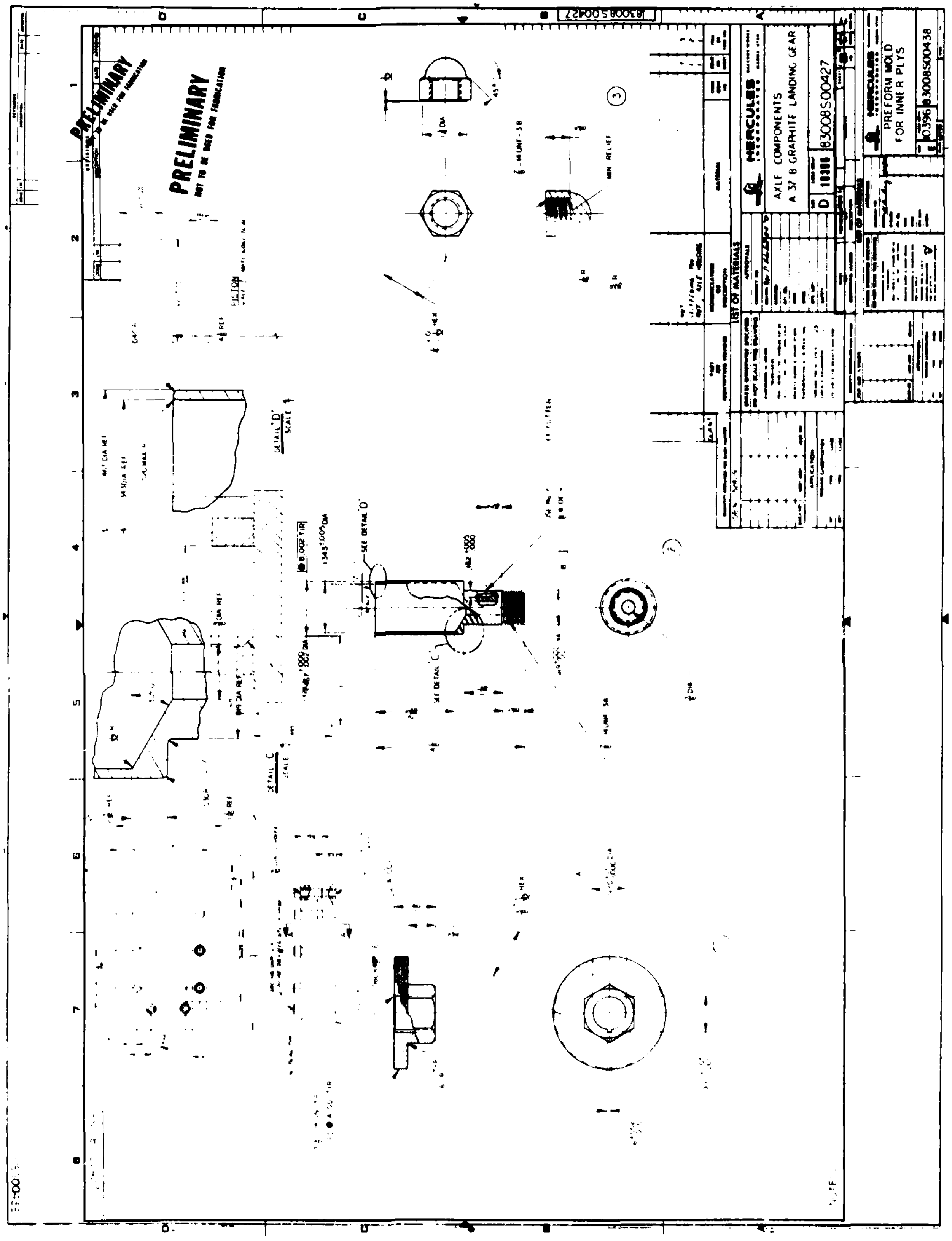
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PREFORM MOLD
FOR INNER PLYS
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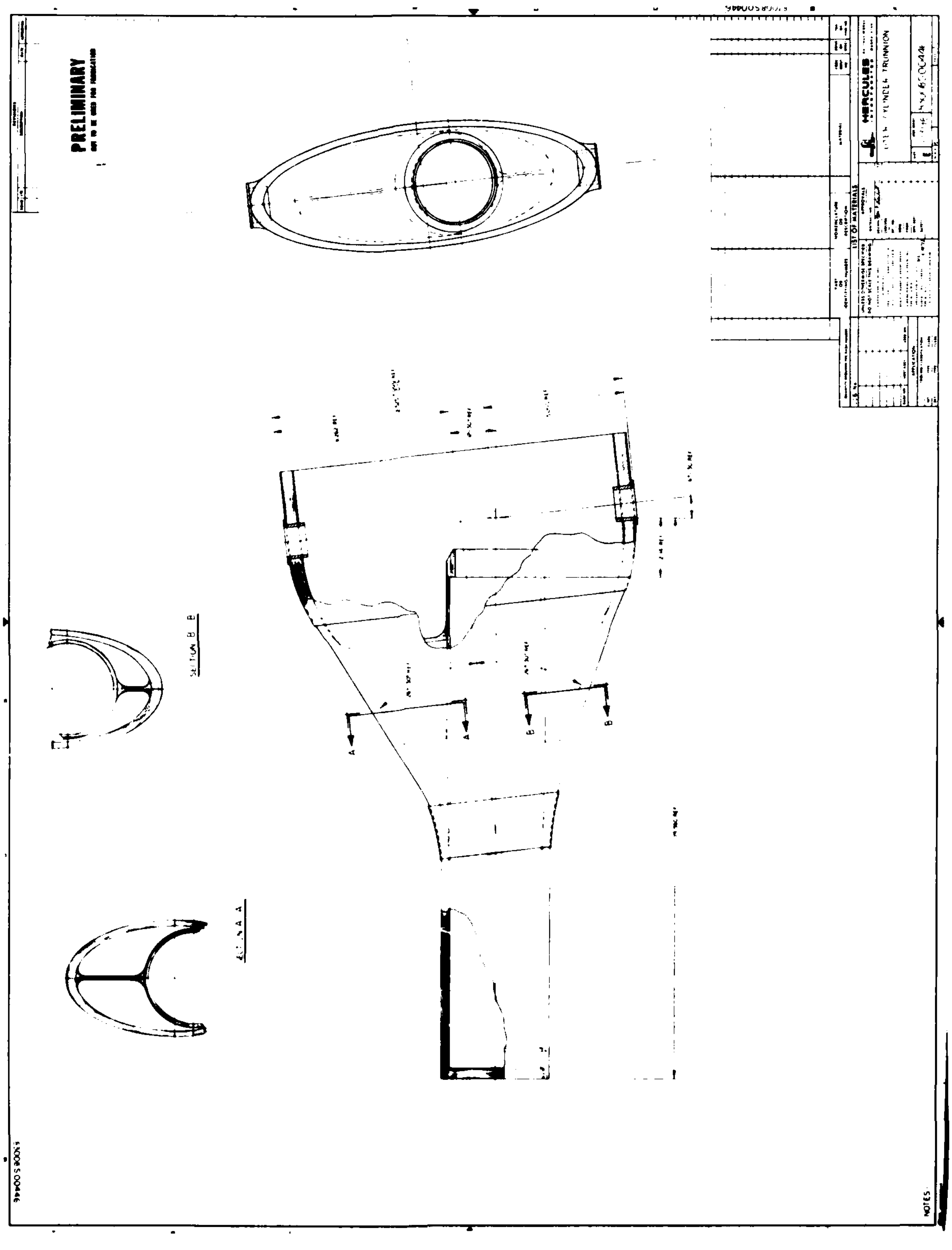
DETAIL 'C' SCALE
SEE DETAIL 'D'
SEE DETAIL 'C'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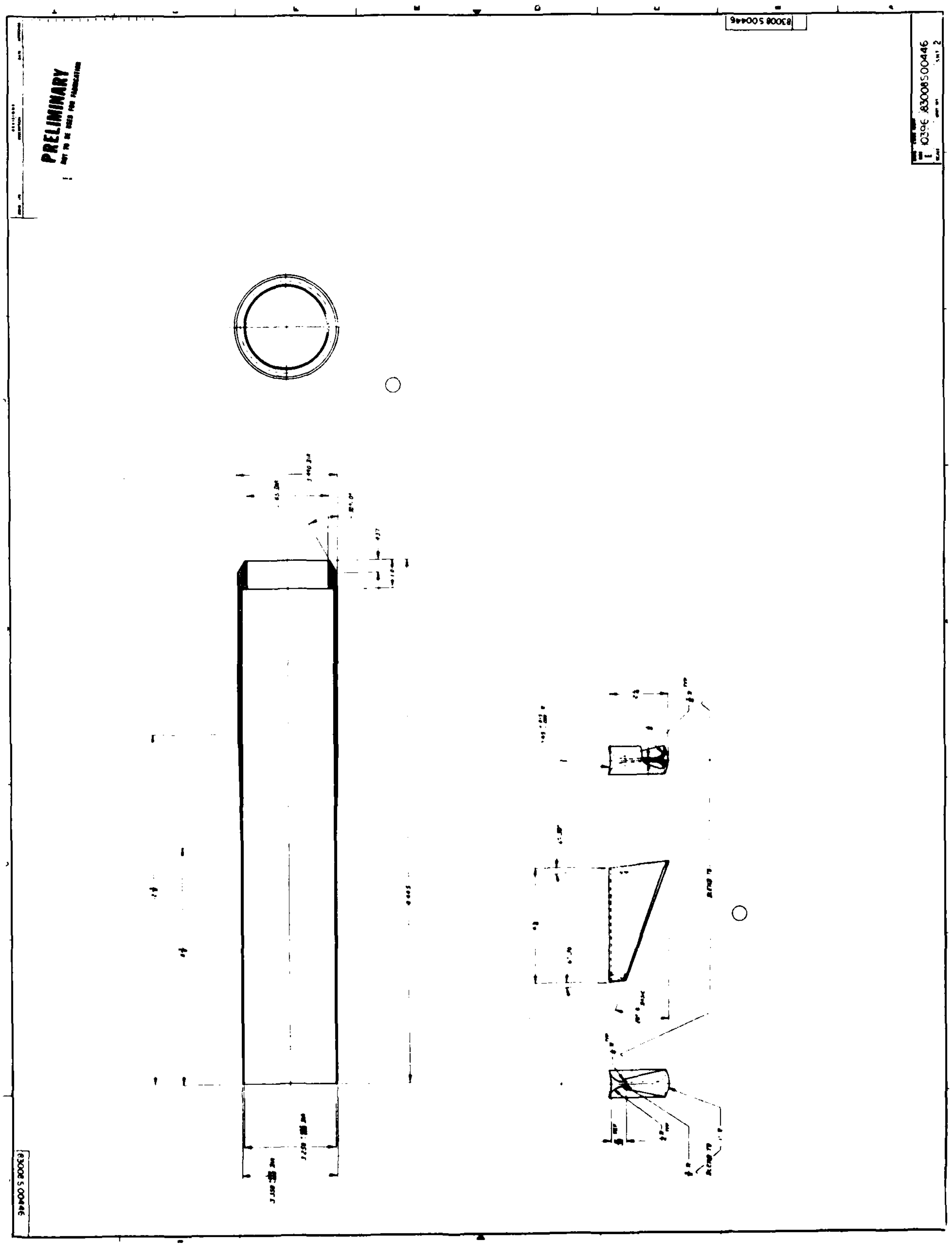
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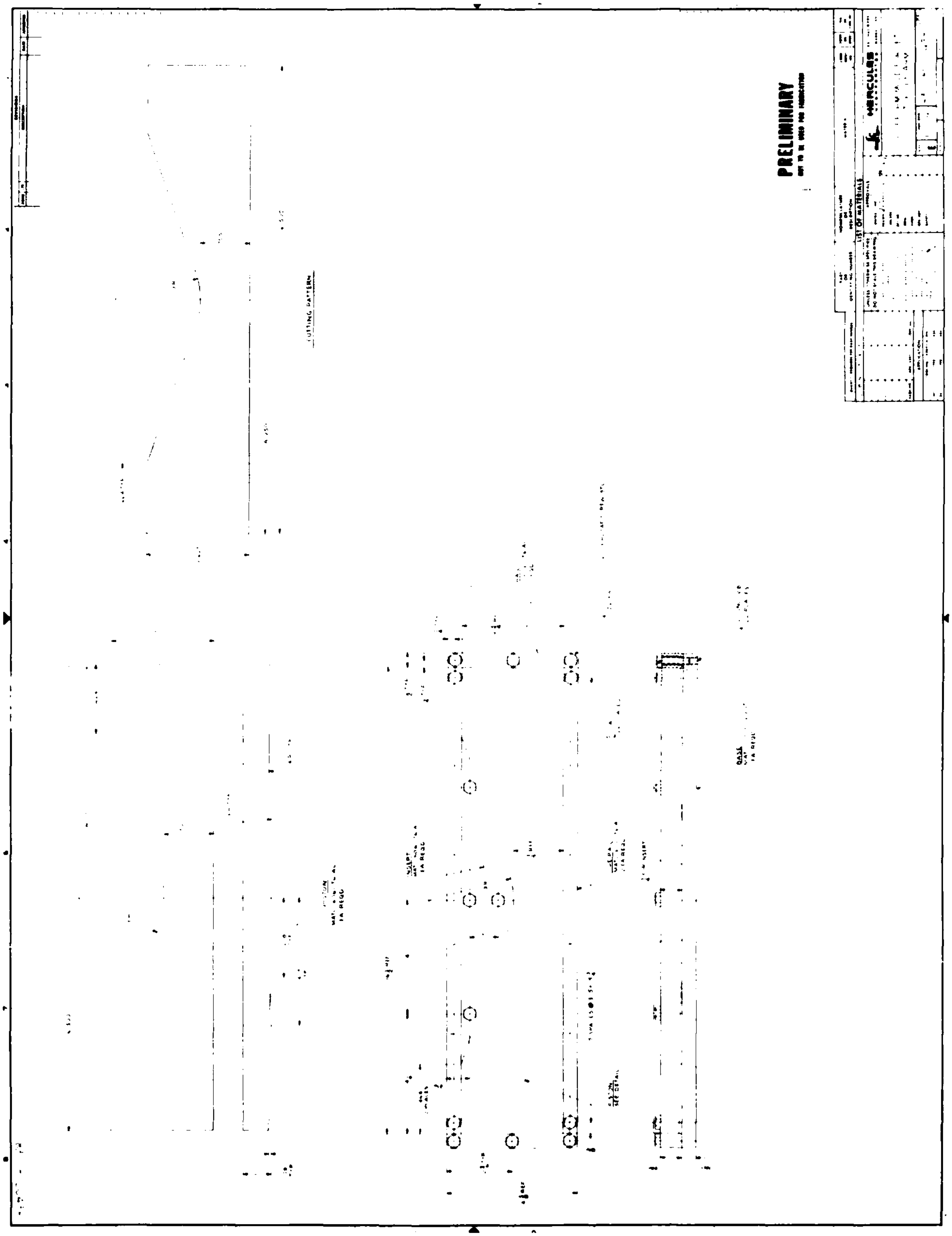
APPENDIX A
PART VII

TOOLING DRAWINGS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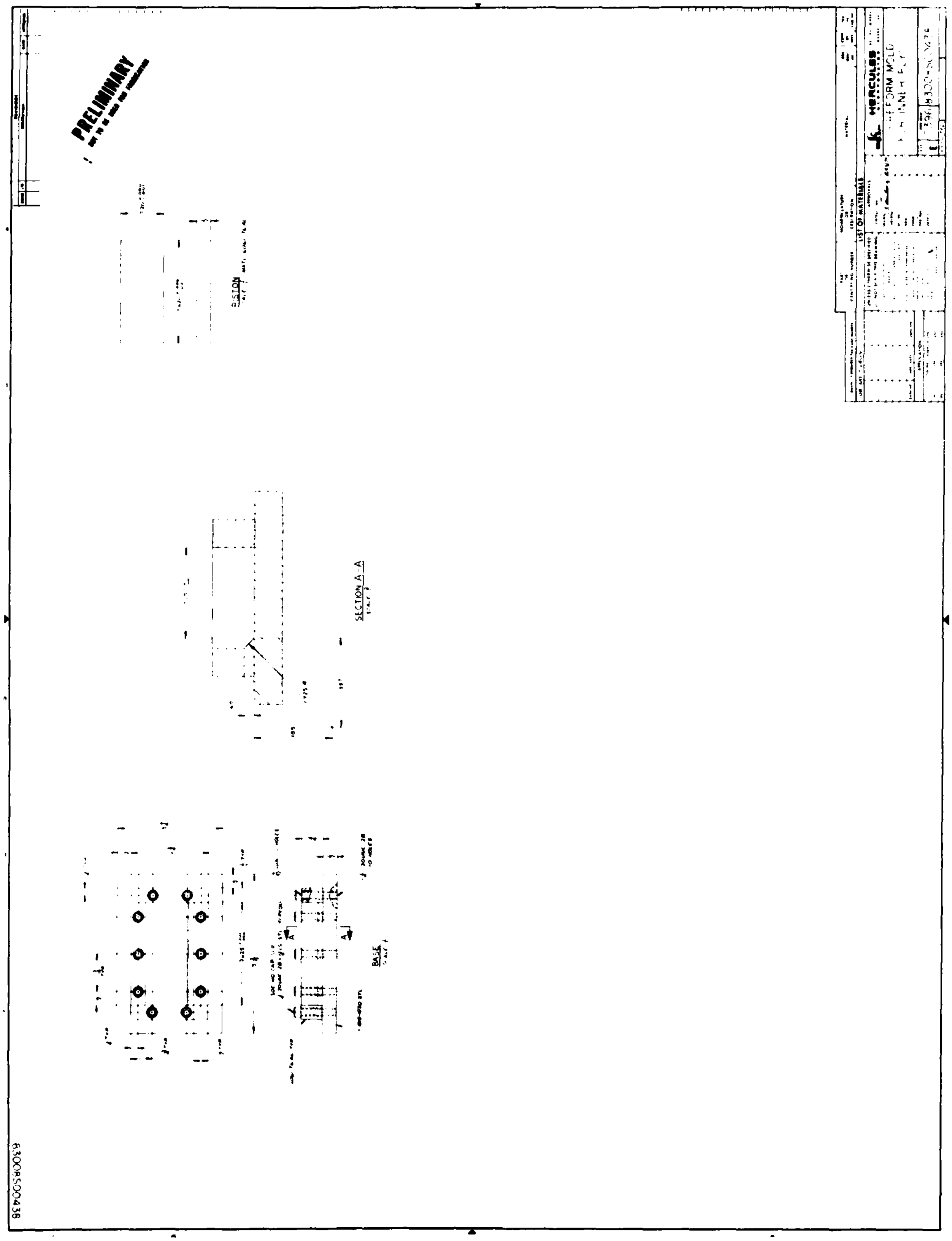
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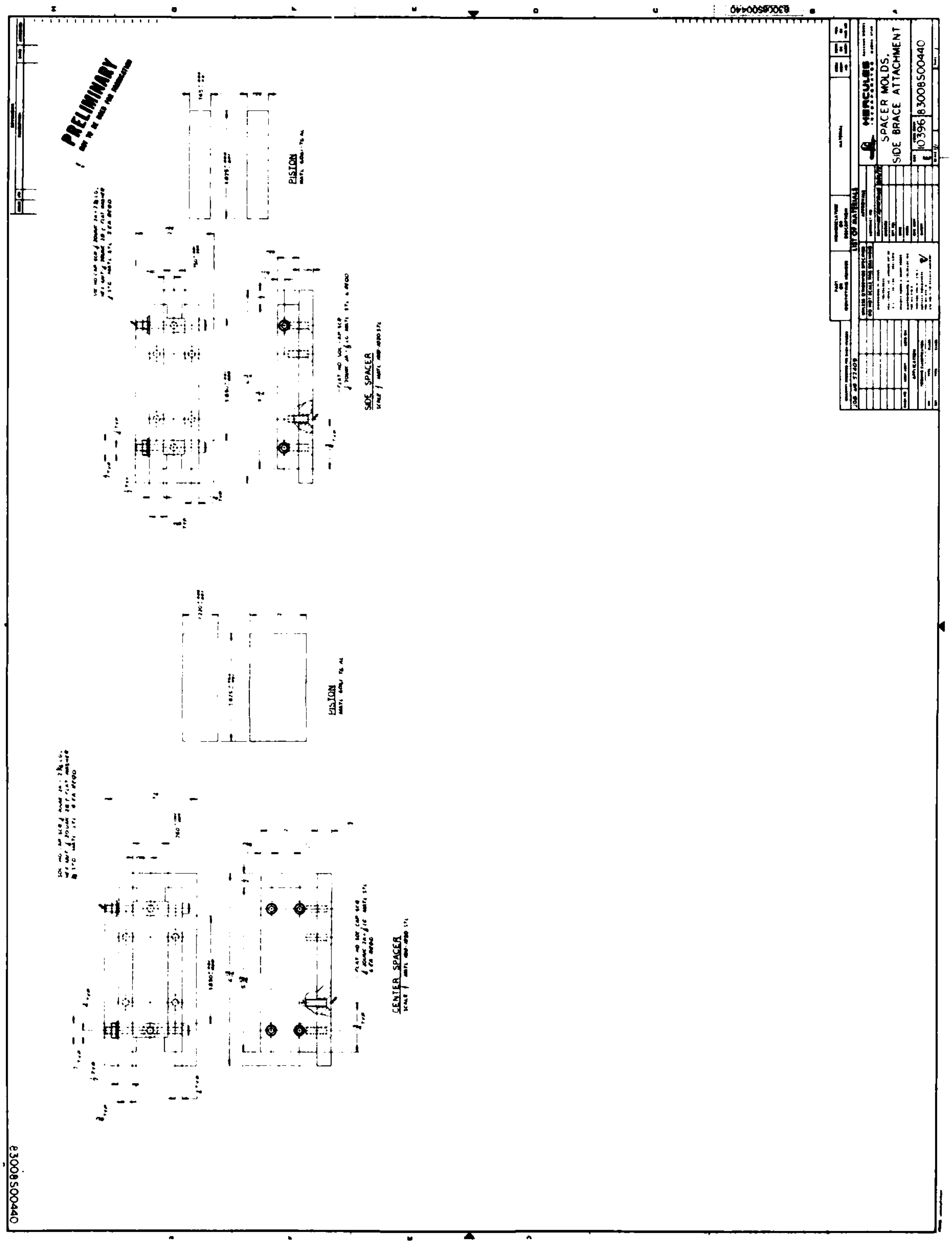
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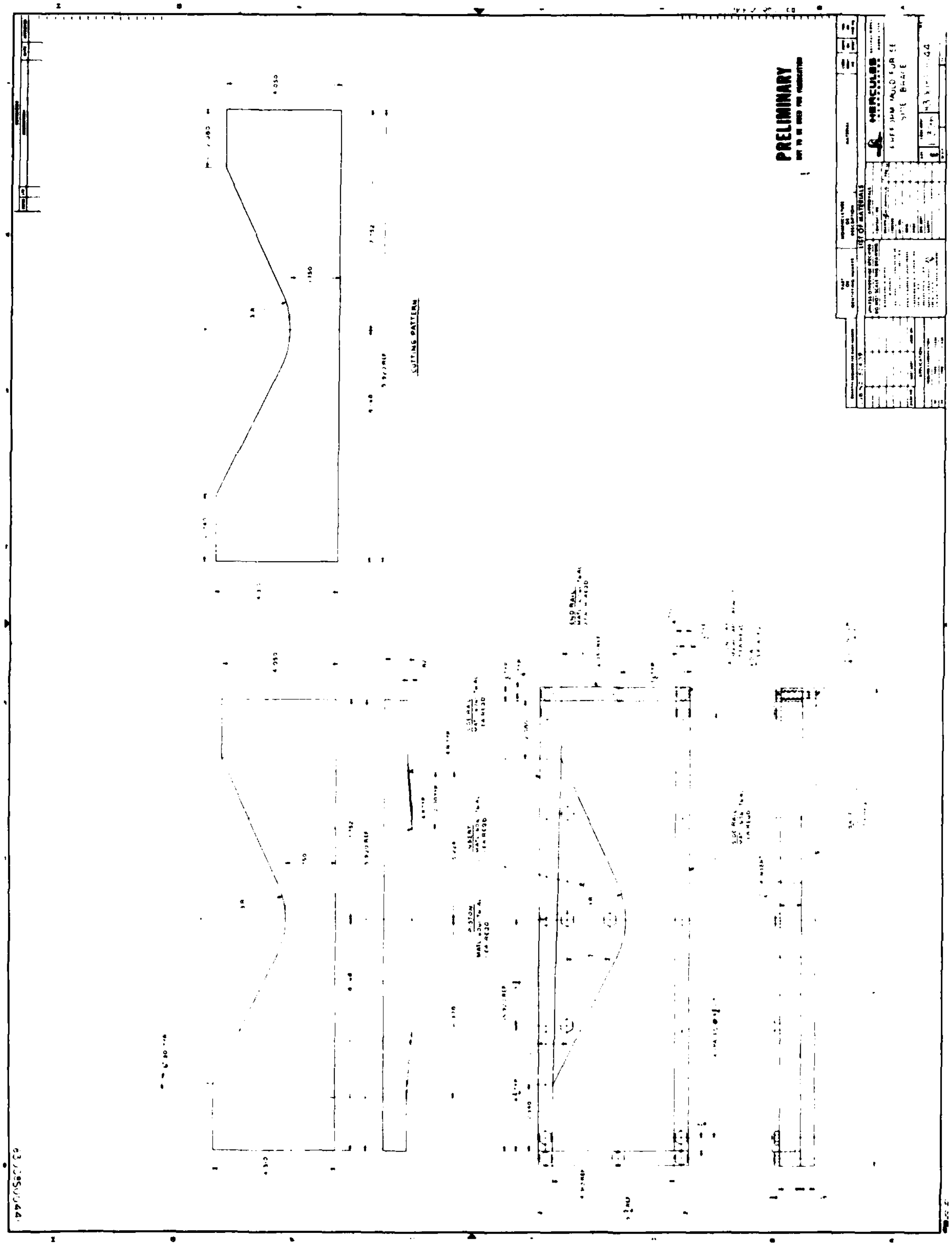
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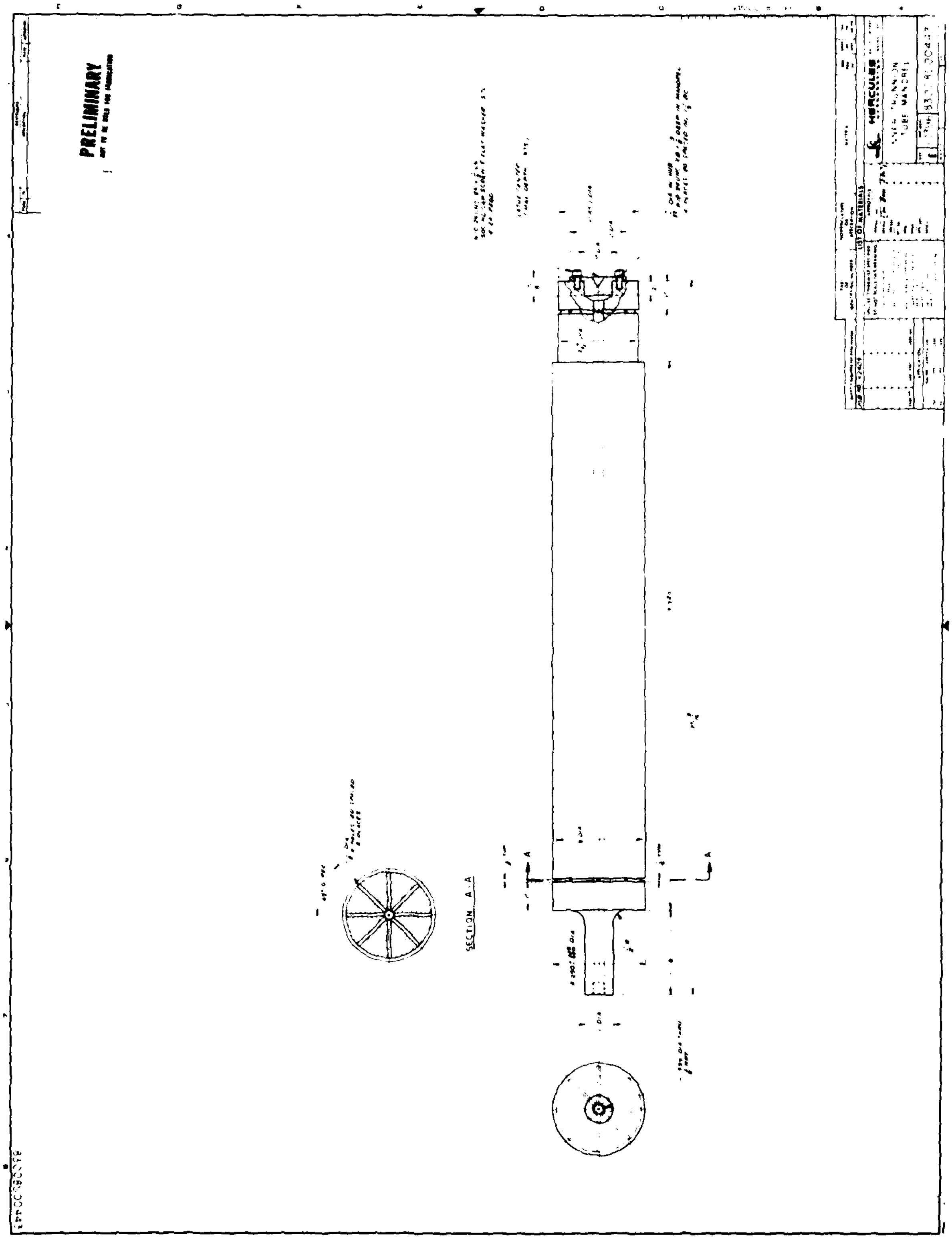
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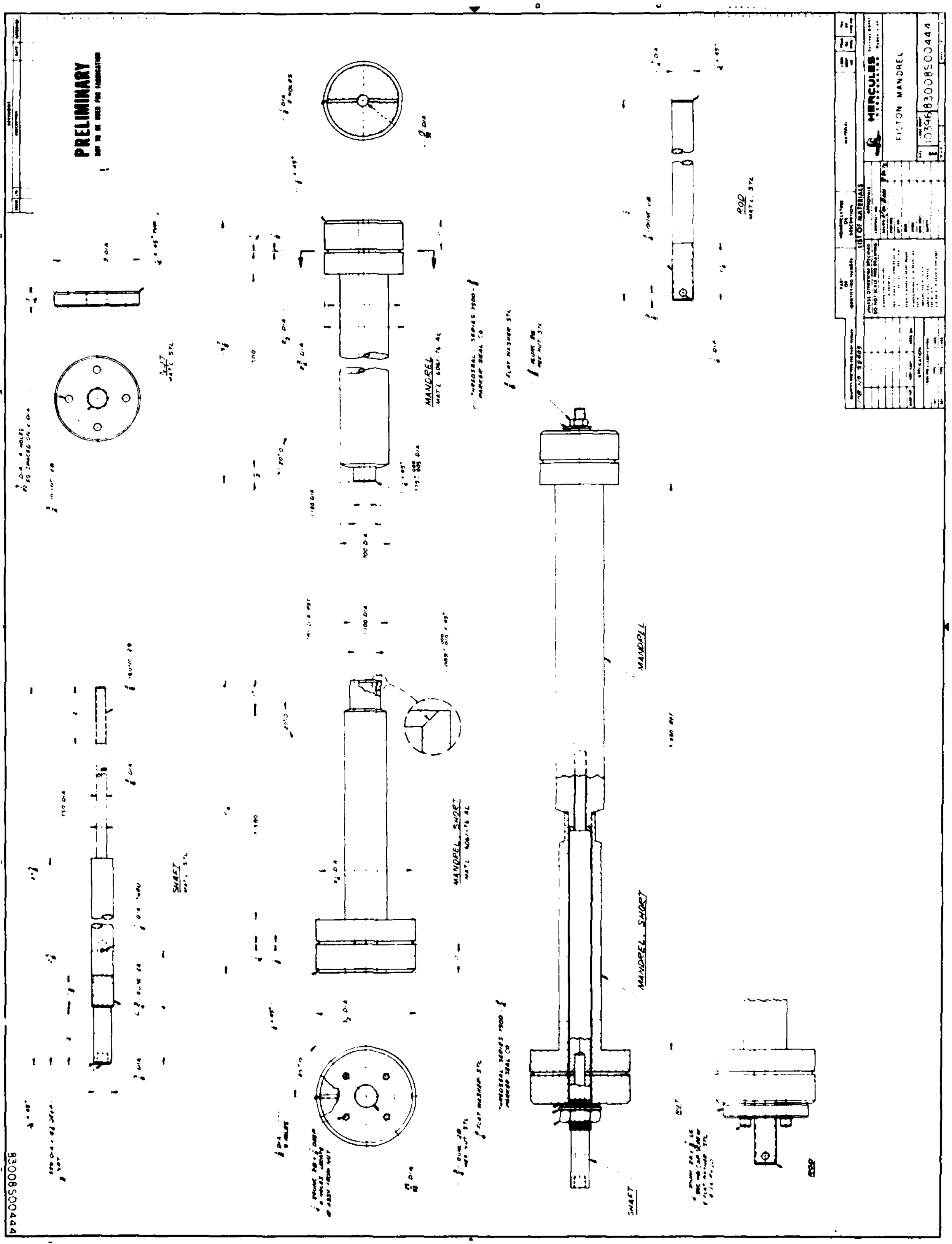
HERCULES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NOT TO BE USED FOR FABRICATION
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SHAFT
ROD
NUT
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PISTON MANDREL
830085O0444

APPENDIX B

FABRICATION OF COMPOSITE LANDING GEAR COMPONENTS

APPENDIX B

FABRICATION OF COMPOSITE LANDING GEAR COMPONENTS

Fabrication of the graphite composite components for the landing gear was performed using a combination of hand layups and tape winding of the plies with frequent compaction steps. Written procedures and M&IR's were used for all composite part fabrication.

The outer cylinder/trunnion was constructed and cured as a unit. The side brace, torque arm attachments, inner cylinder, and gussets were cured separately and bonded in position as the final operation.

The fabrication processes and fabrication tooling are presented in the following paragraphs.

1.0 Torque Arm Attachment

The torque arm attachment is shown on Drawing 83008S00432 (Figures II-1 and II-2). The tools used in the fabrication of the part are the inner ply insert mold (Figure II-3, Drawing 83008S00437), the exterior band set mold (Figure II-4, Drawing 83008S00438) and the layup tool (Figures II-5 and II-6, Drawing 83008S00439). The spacer block (Item 5 of Drawing 83008S00432) was machined from a chopped graphite composite billet so no tooling was required for fabrication.

Using 3501-5/AS prepreg tape, the following fabrication procedures were used:

1.1 Torque Arm Attachment Fabrication Process

A. Inner ply insert preform layup (Mold Drawing 83008S00437)

1. Clean mold with MEK and allow to dry.

2. Apply Frecote #33 mold release to contact surfaces.

3. Cut 36 each 90° plies as shown in Table II-I with the fiber direction in the length direction as shown in Figure II-7.

4. Cut 10 each 0° plies (plies 37 through 46) as shown in Table II-I with the fiber direction in the width direction as shown in Figure II-8.

5. Place all 46 plies sequentially in the mold with ply No. 1 being laid in the mold first. The first ply and all subsequent plies are to be laid in the mold so that the one edge touches the curved portion of the mold as shown in Figure II-9.

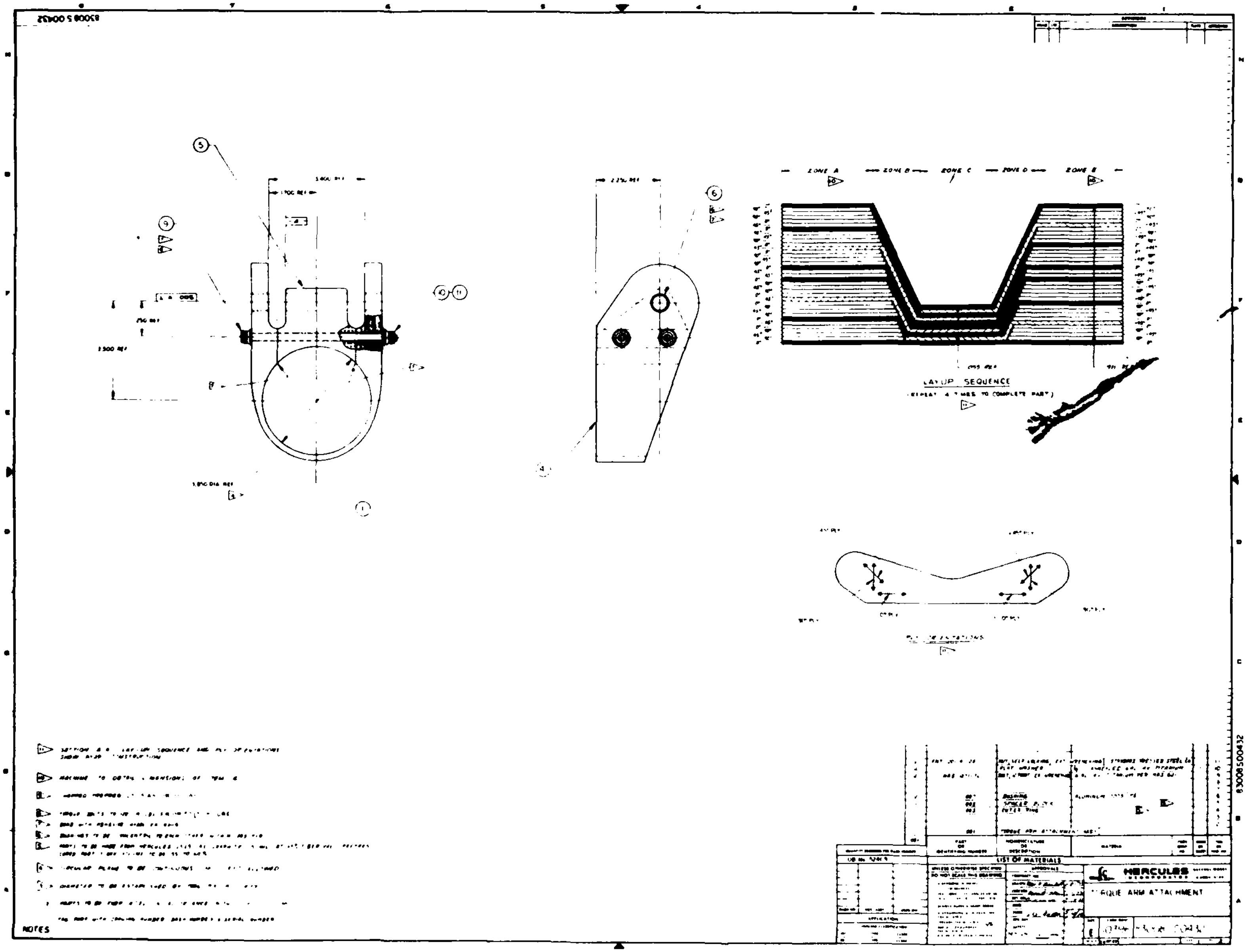


Figure II-1. Torque Arm Attachment, Drawing 83008S00432

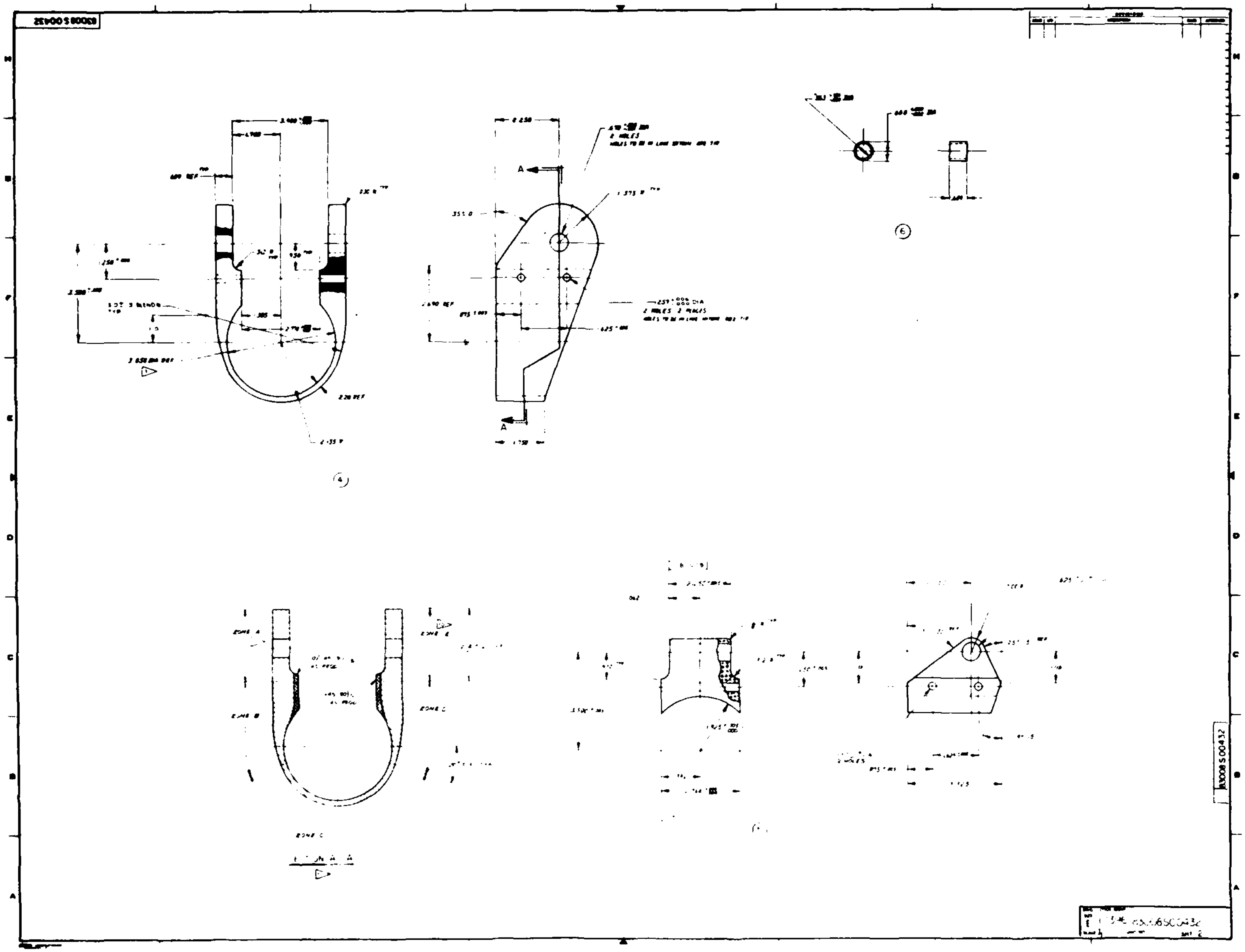


Figure II-2. Torque Arm Attachment, Drawing 83008S00432

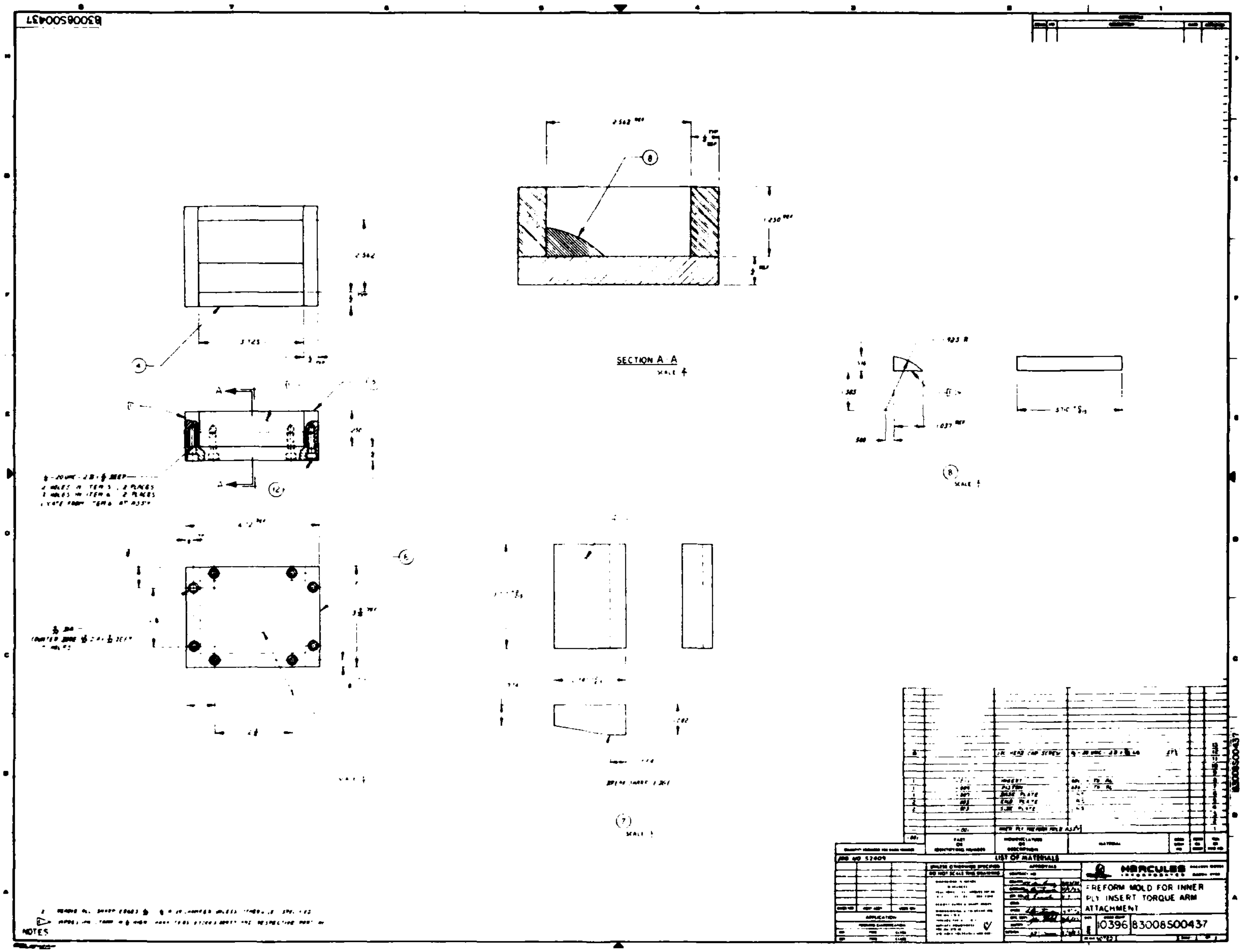


Figure II-3. Inner Ply Insert Mold, Drawing 83008S00437

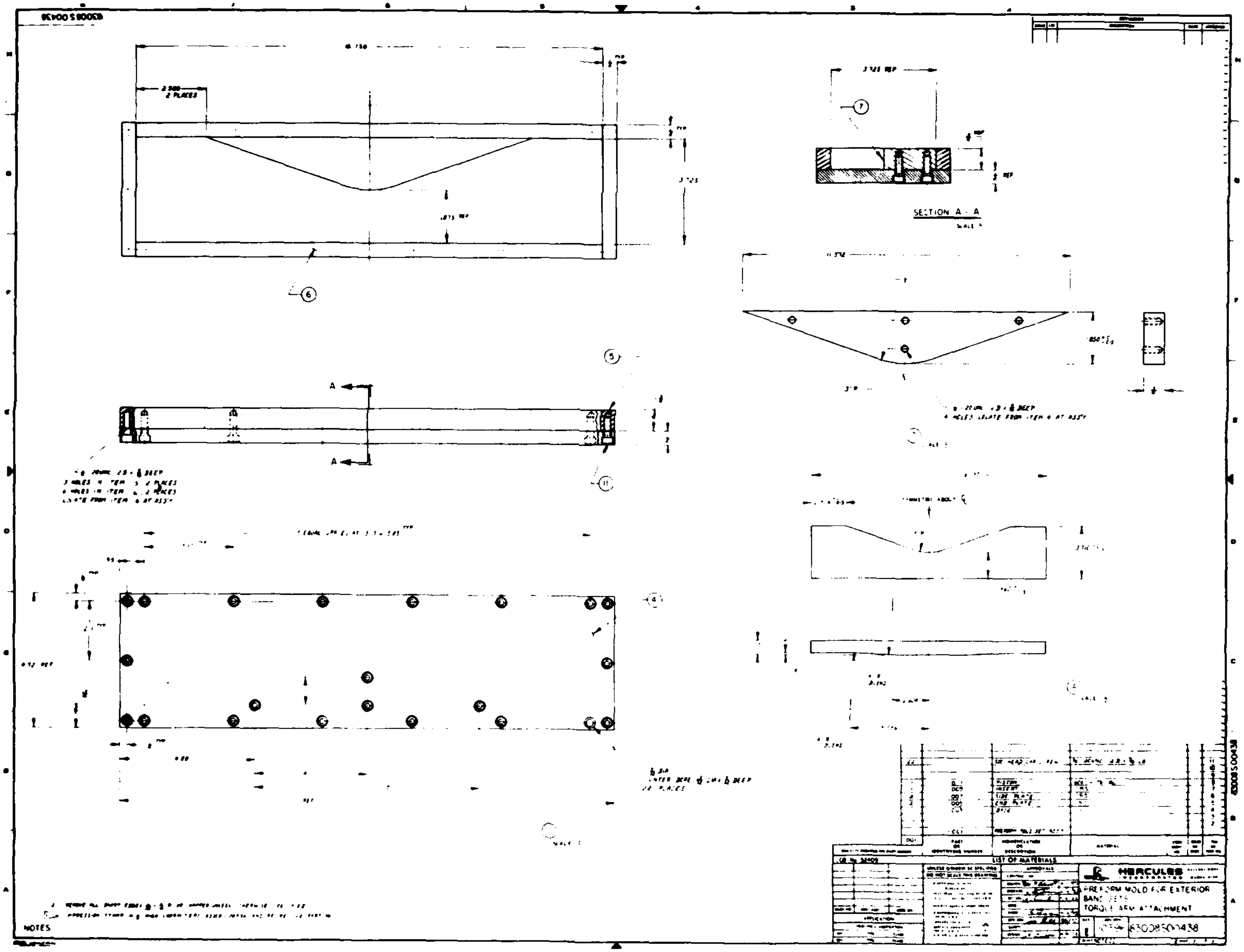


Figure II-4. Exterior Band Set Mold, Torque Arm Attachment
Drawing 83008S00438

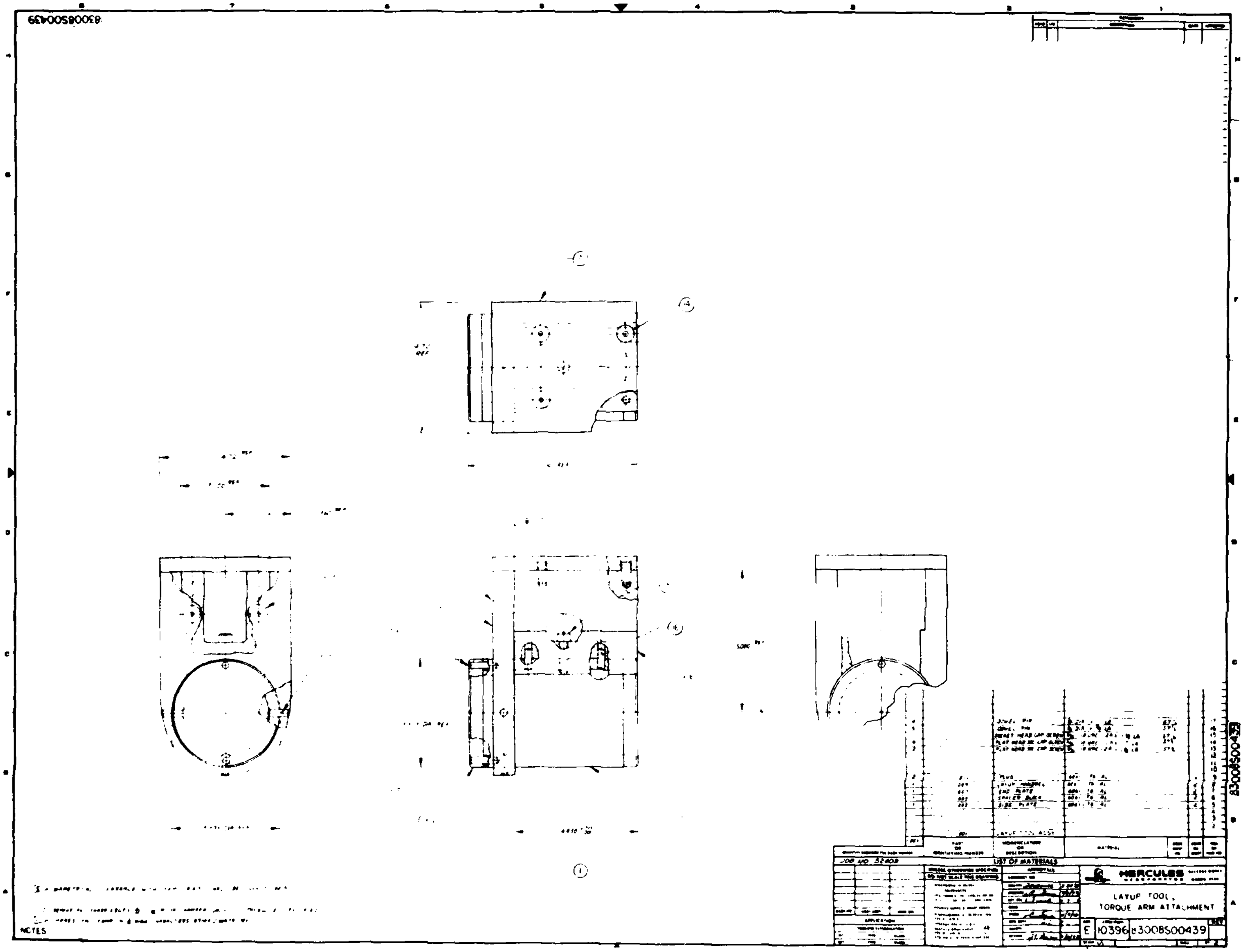


Figure II-5. Layup Tool, T que Arm Attachment, Drawing 83008S00439

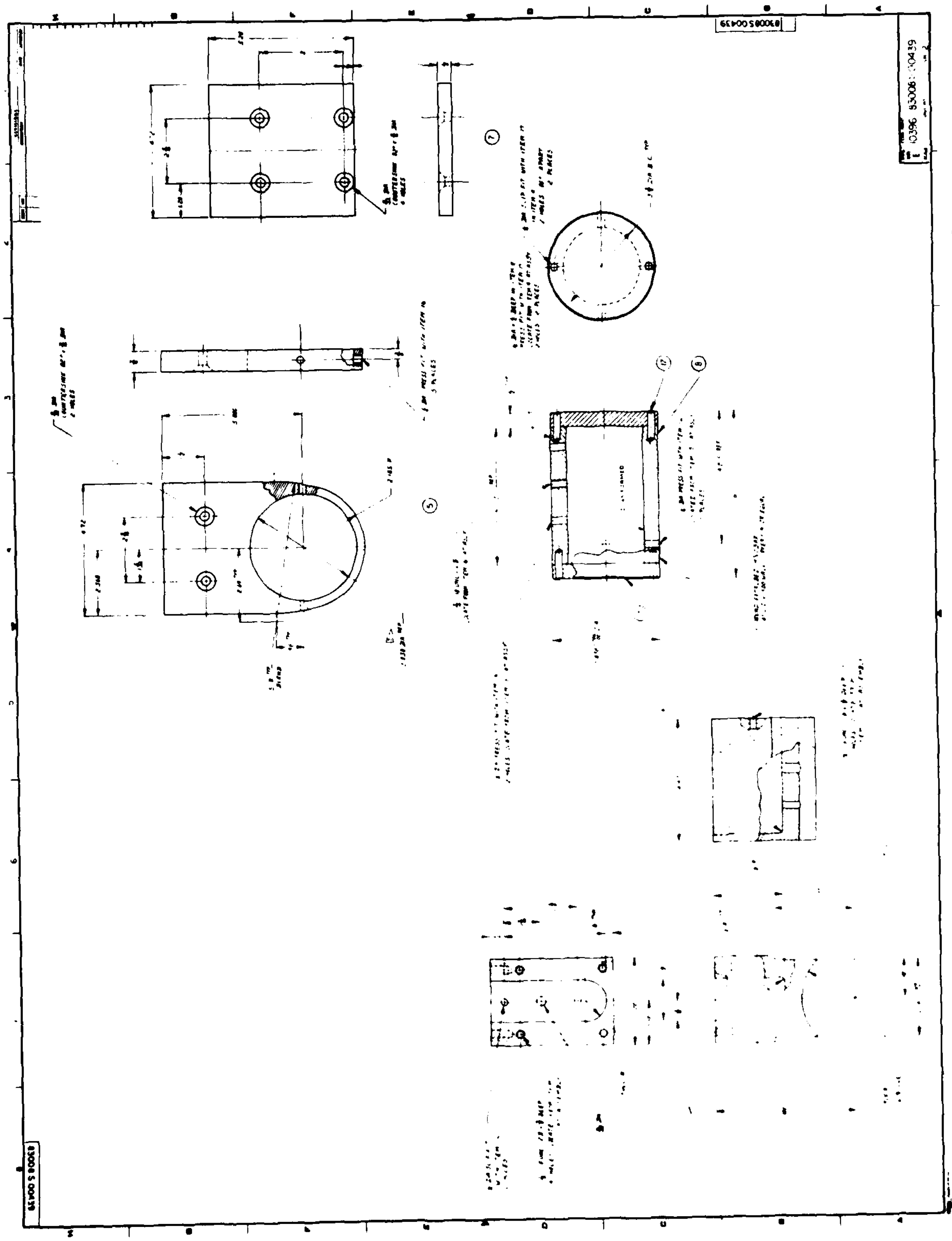
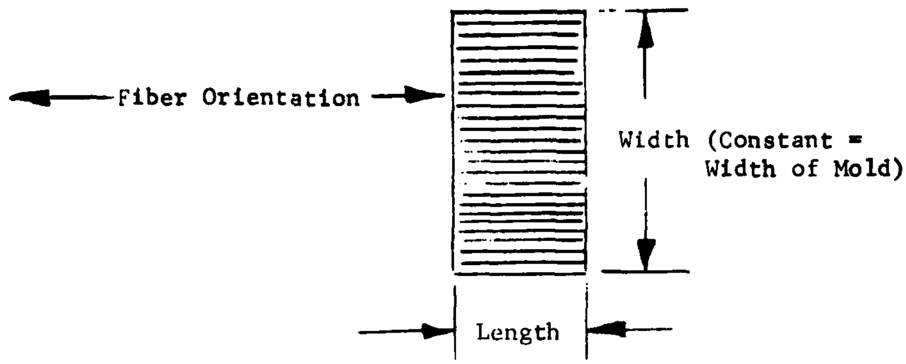


Figure II-6. Layup Tool, Torque Arm Attachment, Drawing 83008S00439, Page 2

Ply No.	Length Figure II-7	Ply No.	Length Figure II-7	Length Figure II-8
1	.800	24	.455	
2	.785	25	.440	
3	.770	26	.425	
4	.755	27	.410	
5	.740	28	.395	
6	.725	29	.380	
7	.710	30	.365	
8	.695	31	.550	
9	.680	32	.335	
10	.665	33	.320	
11	.650	34	.305	
12	.635	35	.290	
13	.620	36	.275	
14	.605	37		.260
15	.590	38		.245
16	.575	39		.230
17	.560	40		.215
18	.545	41		.200
19	.530	42		.170
20	.515	43		.155
21	.500	44		.140
22	.485	45		.125
23	.470	46		.110

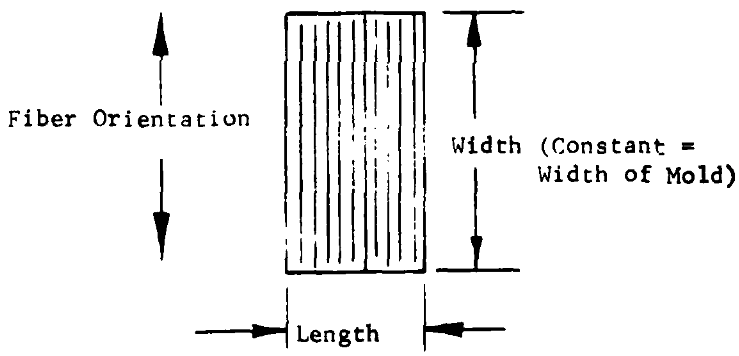
TABLE II-I

INNER PLY INSERT FILLET PLY LENGTH VERSUS PLY NO.



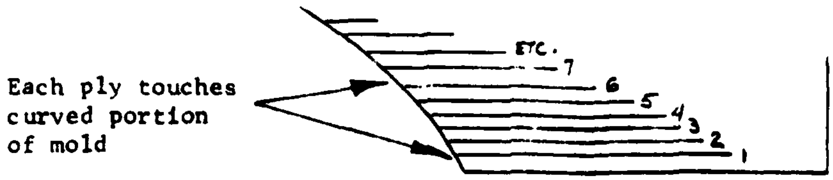
Cutting Pattern for 90° Sets

Figure II-7



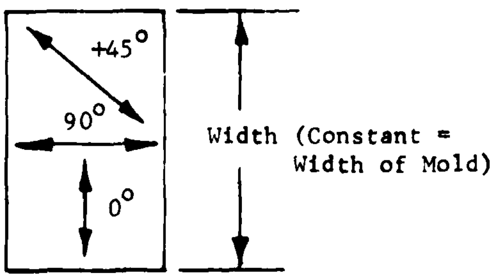
Cutting Pattern for 0° Sets

Figure II-8



Inner Ply Insert Fillet Ply Placement

Figure II-9



Cutting Pattern for +45° Sets

Figure II-10

6. Cut and lay up 11 sets of $[0^{\circ}, +45^{\circ}, 90^{\circ}]_s$. Each set will be cut in the length direction as shown in Table II-II and Figure II-10.

7. Cut and lay up 11 sets of $[0^{\circ}, -45^{\circ}, 90^{\circ}]_s$. Each set will be cut in the length direction as shown in Table II-II and Figure II-11.

8. Place the 11 sets of $[0^{\circ}, +45^{\circ}, 90]_s$ sequentially in the mold with set No. 1 being laid in the mold first. The first set and all subsequent sets are to be laid in the mold as shown in Figure II-12 with the one edge touching the vertical portion of the mold opposite the curved metal insert.

9. Place piston in mold (Figure II-13) and place assembly in press. Set pressure to 200 psi. Hold temperature and pressure for 10 minutes. Maintain pressure and reduce temperature. Remove pressure when part is at room temperature or below.

10. Strip inner ply insert from mold.

11. Repeat Steps A1 through A4.

12. Place the 11 sets of $[0^{\circ}, -45^{\circ}, 90]_s$ (made in Step 7) sequentially in the mold as was done in Step 8.

13. Repeat Steps 9 and 10.

B. Exterior band sets (Item 4 of Drawing 83008S00432; Mold Drawing 83008S00438)

1. Clean mold with MEK.

2. Apply Frecote mold release to contact surfaces.

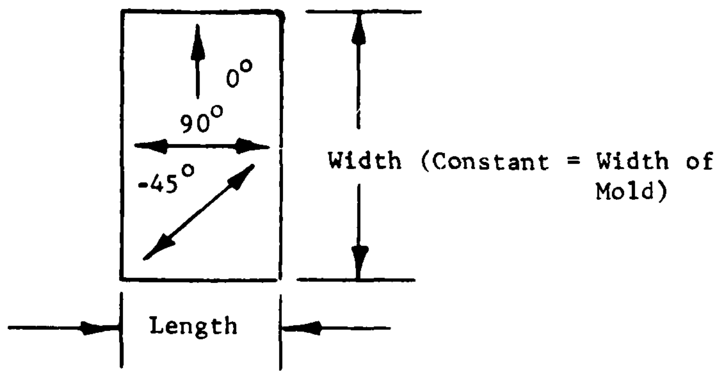
3. Cut out and lay up preform set No. 1 in the mold. The orientation, length and ply number within the set are given in Table II-III. The cutting pattern and layup sequence for the set are shown in Figures II-14 and II-15.

4. Place the piston in the mold and the assembly in the press. "B" stage at 200°F and 200 psi for 10 minutes. Cool under pressure.

Set No.	Length
1	1.75
2	1.84
3	1.92
4	2.00
5	2.09
6	2.18
7	2.26
8	2.34
9	2.43
10	2.52
11	2.60

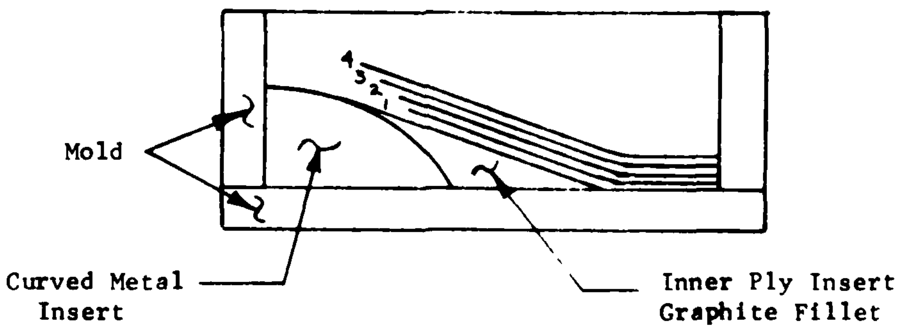
TABLE II-II

INNER PLY INSERT SET LENGTH VERSUS SET NO.
$[0^\circ, +45^\circ, 90^\circ]_s$ or $[0^\circ, -45^\circ, 90^\circ]_s$



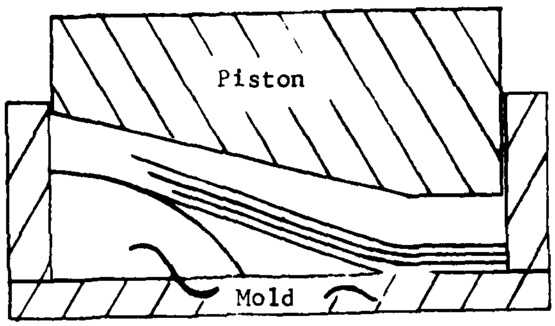
Cutting Pattern for -45° Sets

Figure II-11



Position of Inner Ply Insert in Mold

Figure II-12



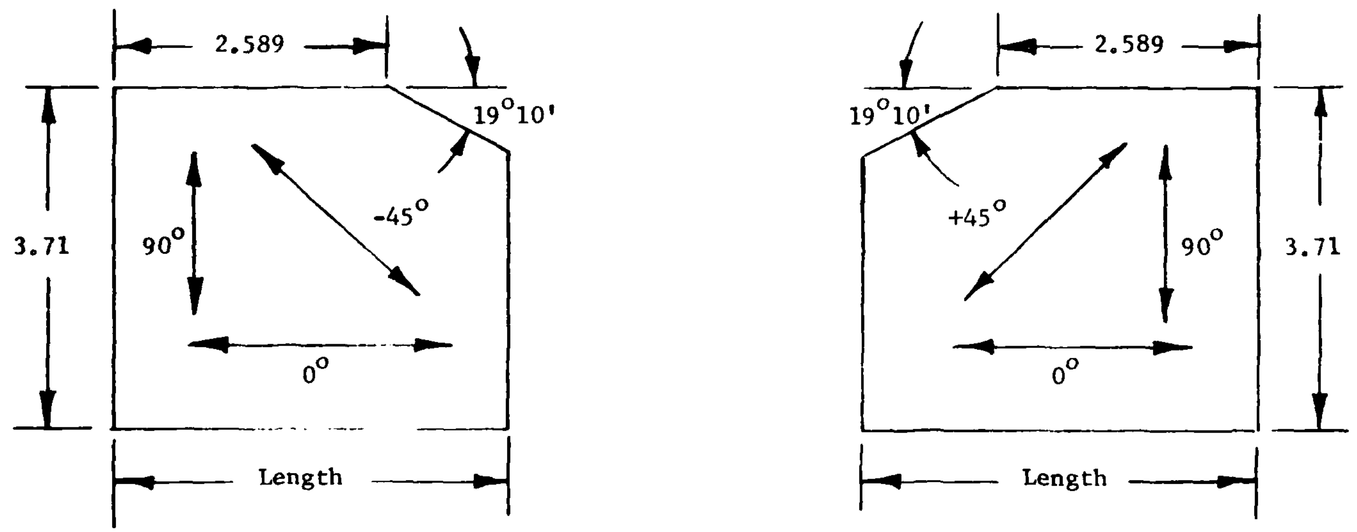
Piston-Mold Assembly

Figure II-13

Ply No.	Length	Left Side Orientation	Right Side Orientation
1	Full	0°	0°
2L	5.60	90°	--
2R	5.60	--	90°
3L	5.45	-45°	--
3R	5.45	--	$+45^{\circ}$
4L	5.30	90°	--
4R	5.30	--	90°
5L	5.15	0°	--
5R	5.15	--	0°
6L	5.00	-45°	--
6R	Butt to Ply 2L	--	$+45^{\circ}$
7L-11R	Full	0°	0°
8L	4.85	90°	--
8R	4.85	--	90°
9L	4.70	-45°	--
9R	4.70	--	$+45^{\circ}$
10L	4.55	90°	--
10R	4.55	--	90°
11L	4.40	0°	--
12L	Butt to Ply 12R	-45°	--
12R	4.40	--	$+45^{\circ}$
13L	4.25	0°	--
13R	4.25	--	0°
14L	4.10	90°	--
14R	4.10	--	90°
15L	3.95	-45°	--
15R	3.95	--	$+45^{\circ}$
16L	3.80	90°	--
16R	3.80	--	90°
17	Full	0°	0°
18L	3.65	-45°	--
18R	3.65	--	$+45^{\circ}$
19L	3.50	-45°	--
19R	3.50	--	$+45^{\circ}$
20	Full	0°	0°
21L	3.35	90°	--
21R	3.35	--	90°
22L	3.20	-45°	--
22R	3.20	--	$+45^{\circ}$
23L	3.05	90°	--
23R	3.05	--	90°
24L	2.90	0°	--
24R	2.90	--	0°
25L	Butt to Ply 21R	-45°	--
25R	2.75	--	$+45^{\circ}$

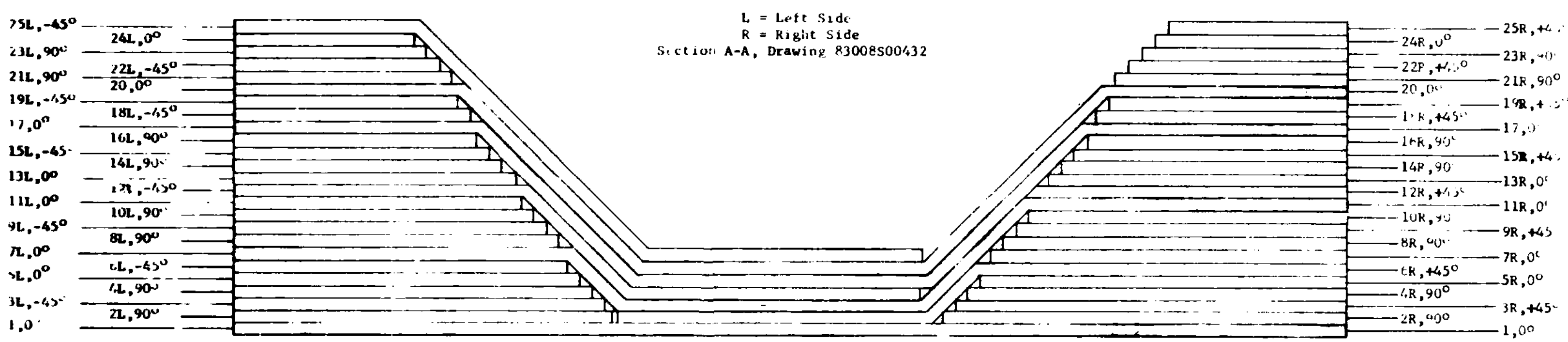
TABLE II-III

EXTERIOR BAND SETS, TORQUE ARM ATTACHMENT
SETS NO. 1 AND 4, PLY LENGTH VERSUS ORIENTATION



Cutting Pattern
Sets 1, 2, 3, 4, 5 and 6

Figure II-14



Torque Arm Attachment
Sets No. 1 and 4
Layup Sequence

Figure II-15

5. Strip preform set from mold.

6. Fabricate preform set No. 4 by repeating Steps 1, 2, 3, 4 and 5.

7. Repeat Steps 1 and 2.

8. Cut out and lay up preform set No. 2 in the mold. The orientation, length and ply number within the set are given in Table II-IV. The cutting pattern and layup sequence for the set are shown in Figures II-14 and II-16.

9. Repeat Steps 4 and 5.

10. Fabricate preform set No. 5 by repeating Steps 1, 2, 8, 4 and 5.

11. Repeat Steps 1 and 2.

12. Cut out and lay up preform set No. 3 in the mold. The orientation, length and ply number within the set are given in Table II-V. The cutting pattern and layup sequence for the set are shown in Figures II-14 and II-17.

13. Repeat Steps 4 and 5.

14. Fabricate preform set No. 6 by repeating Steps 1, 2, 12, 4 and 5.

C. Forming exterior band sets on layup mandrel (Mandrel Drawing 83008S00439)

1. Place layup mandrel in oven and heat to 200°F.

2. Using hot mandrel, drape each exterior band set (fabricated in Section B) over the mandrel so that they conform approximately to the shape of the mandrel. This is a rough forming operation so each set will be about the same shape.

D. Final assembly (Mandrel Drawing 83008S00439)

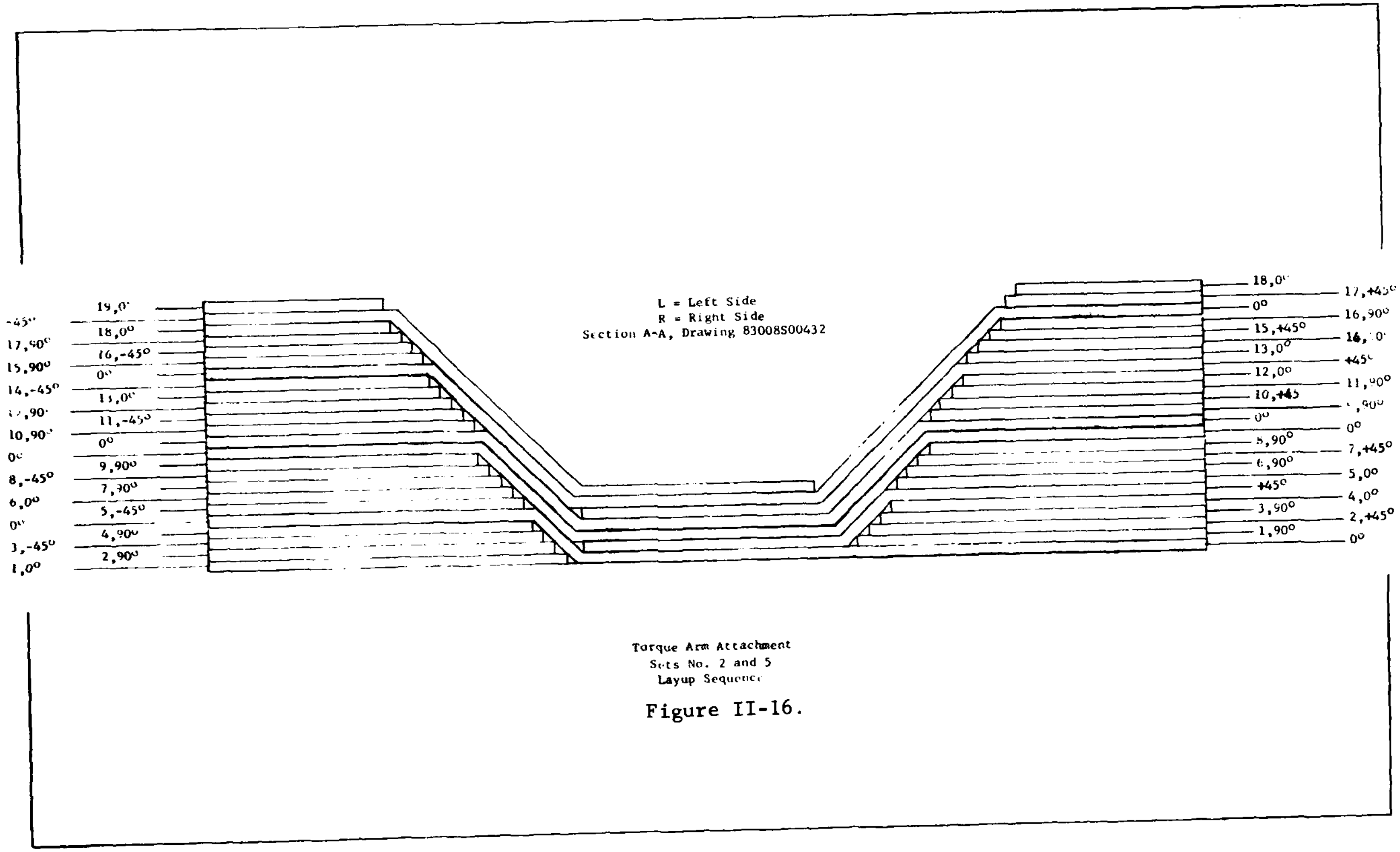
1. Fabricate an exterior aluminum sheet metal (.050 in.) caul plate that will conform to the outside dimensions of the cured band sets. Refer to Drawing 83008S00432 for dimensions.

2. Heat the layup mandrel to 200°F and place the two inner ply insert preforms in position. (See Figure II-18.)

Ply No.	Length	Left Side Orientation	Right Side Orientation
1L	5.60	0^o	--
5L-1R	Full	0^o	0^o
2L	5.45	90^o	--
2R	5.45	--	90^o
3L	5.30	-45^o	--
3R	5.30	--	$+45^o$
4L	5.15	90^o	--
4R	5.15	--	90^o
5R	5.00	--	0^o
6L	5.00	-45^o	--
6R	Butt to Ply 6L	--	$+45^o$
7L	4.85	0^o	--
7R	4.85	--	0^o
8L	4.70	90^o	--
8R	4.70	--	90^o
9L	4.55	-45^o	--
9R	4.55	--	$+45^o$
10L	4.40	90^o	--
10R	4.40	--	90^o
11	Full	0^o	0^o
12	Full	0^o	0^o
13L	4.25	90^o	--
13R	4.25	--	90^o
14L	4.10	-45^o	--
14R	4.10	--	$+45^o$
15L	3.95	90^o	--
15R	3.95	--	90^o
16L	3.80	0^o	--
16R	3.80	--	0^o
17L	3.65	-45^o	--
17R	Butt to Ply 12L	--	$+45^o$
18L-22R	Full	0^o	0^o
18R	3.65	--	0^o
19L	3.50	90^o	--
19R	3.50	--	90^o
20L	3.35	-45^o	--
20R	3.35	--	$+45^o$
21L	3.20	90^o	--
21R	3.20	--	90^o
22L	3.05	0^o	--
23L	Butt to Ply 22R	-45^o	--
23R	3.05	--	$+45^o$
24L	2.90	0^o	--
24R	2.90	--	0^o

TABLE II-IV

EXTERIOR BAND SETS, TORQUE ARM ATTACHMENT
SETS NO. 2 AND 5, PLY LENGTH VERSUS ORIENTATION



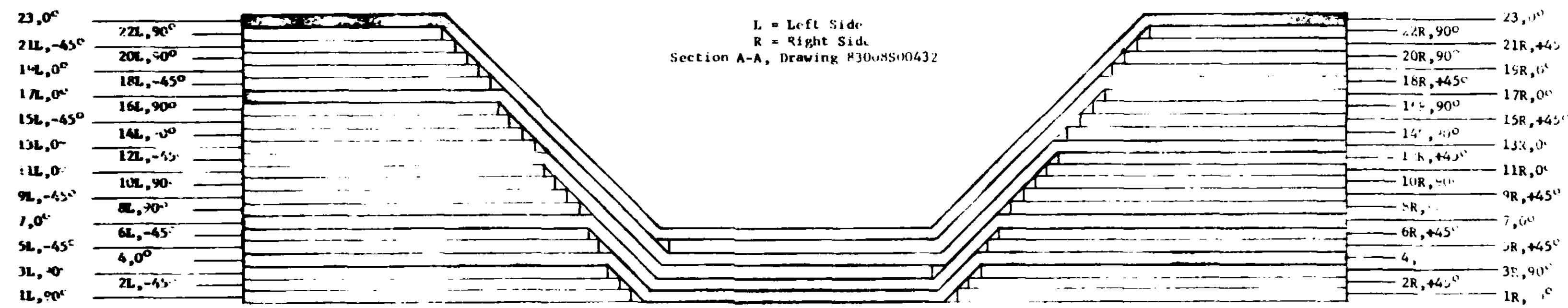
Torque Arm Attachment
Sets No. 2 and 5
Layup Sequence

Figure II-16.

Ply No.	Length	Left Side Orientation	Right Side Orientation
1L	5.60	90^o	--
1R	5.60	--	90^o
2L	5.45	-45^o	--
2R	5.45	--	$+45^o$
3L	5.30	90^o	--
3R	5.30	--	90^o
4	Full	0^o	0^o
5L	5.15	-45^o	--
5R	5.15	--	$+45^o$
6L	5.00	-45^o	--
6R	5.00	--	$+45^o$
7	Full	0^o	0^o
8L	4.85	90^o	--
8R	4.85	--	90^o
9L	4.70	-45^o	--
9R	4.70	--	$+45^o$
10L	4.55	90^o	--
10R	4.55	--	90^o
11L	4.40	0^o	--
11R	4.40	--	0^o
12L	Butt to Ply 8R	-45^o	--
12R	4.25	--	$+45^o$
13L	4.25	0^o	--
17L-13R	Full	0^o	0^o
14L	4.10	90^o	--
14R	4.10	--	90^o
15L	3.95	-45^o	--
15R	3.95	--	$+45^o$
16L	3.80	90^o	--
16R	3.80	--	90^o
17R	3.65	--	0^o
18L	3.65	-45^o	--
18R	Butt to Ply 18L	--	$+45^o$
19L	3.50	0^o	--
19R	3.50	--	0^o
20L	3.35	90^o	--
20R	3.35	--	90^o
21L	3.20	-45^o	--
21R	3.20	--	$+45^o$
22L	3.05	90^o	--
22R	3.05	--	90^o
23	Full	0^o	0^o

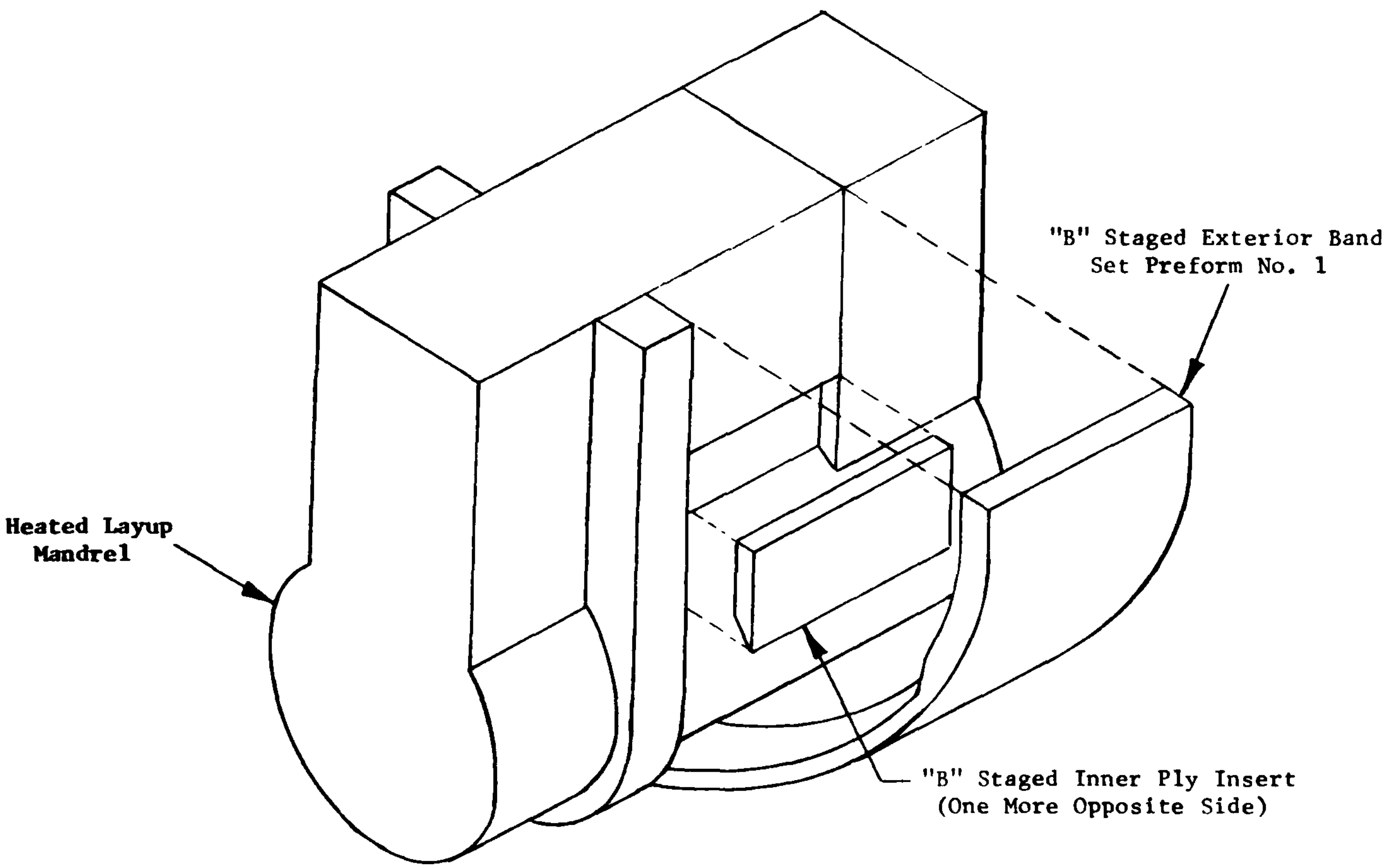
TABLE II-V

EXTERIOR BAND SETS, TORQUE ARM ATTACHMENT
SETS NO. 3 AND 6, PLY LENGTH VERSUS ORIENTATION



Torque Arm Attachment
Sets No. 3 and
Layup Sequence

Figure II-17



Torque Arm Attachment Preform Layup

Figure II-18

3. Place exterior band set No. 1 in position (see Figure II-17) and sequentially add band sets Nos. 2, 3, 4, 5 and 6.

4. Place the caul plate over band set No. 6.

5. Wrap the assembly with TX-1040 release fabric.

6. Wrap this assembly with 12 end glass roving using the No. 21 Winding Machine to rotate the mandrel. Set the torque motor at 70 units to apply proper roving tension.

7. Cool the assembly and remove the glass roving, TX-1040 and caul plate.

8. Trim excess prepreg at top of mandrel and place end plate (Item 7 of Drawing 83008S00439) on mandrel.

E. Final cure

1. Replace caul plate and TX-1040 and wrap assembly with 12 end glass roving.

2. Install vacuum bag over this assembly and cure in autoclave.

3. Cure cycle:

   a. Hold vacuum throughout cure cycle.

   b. Raise temperature 3°/minute to 250°F.

   c. Apply 100 psi at 200°F level.

   d. Hold at 250°F for 4 hours.

   e. Raise temperature at 3°/minute to 300°F.

   f. Hold for 1 hours at 300°F and 100 psi.

   g. Cool down with 100 psi pressure to room temperature (or 150°F maximum).

F. Spacer block fabrication (Item 5 of Drawing 83008S00438)

1. Cut up 5 lbs of 3501/AS prepreg (.005 in. thick) into 1/2 in. x 1/2 in. pieces.

2. Using a standard 4.75 in. diameter slug mold, pack the cavity with 5 lbs of chopped 3501/AS prepreg.

3. Place piston in mold and place assembly in press.

4. Raise temperature to 250^{o}F and apply 2000 psi for 1/2 hour.

5. Raise temperature to 350^{o}F and apply 2000 psi for 2 hours.

6. Cool down and strip billet from mold.

7. Machine billet to configuration of Item 5 of Drawing 83008S00438.

2.0 Side Brace Attachment

The side brace attachment is shown on Drawing 83008S00433 (Figure II-19 and II-20). The tools used in the fabrication of the part are the exterior band set mold (Figure II-21, Drawing 83008S00441) and the layup tool (Figures II-22 and II-23, Drawing 83008S00445). The spacing block (Item 8 of Drawing 83008S00433) was machined from a chopped graphite composite billet so no tooling was required for fabrication. The outer spacer right and outer spacer left (Items 4 and 5 of Drawing 83008S00433) were machined from a graphite composite flat plate so no tooling was required for fabrication.

Using 3501-5/AS prepreg 3-in. tape, the following fabrication procedures were used:

2.1 Side Brace Attachment Fabrication Procedure

A. Exterior band sets (Item 3 of Drawing 83008S00433; Mold Drawing 83008S00441)

1. Clean mold with MEK and allow to dry.

2. Apply Frecote #33 mold release to contact surfaces.

3. Cut out and lay up preform set No. 1 in the mold. The orientation, length and ply number within the set are given in Table II-VI. The cutting pattern and layup sequence for the set are shown in Figures II-24 and II-25.

4. Place the piston in the mold and the assembly in the press. "B" stage at 200^{o} F and 200 psi for 10 minutes. Cool under pressure.

5. Strip preform set from mold.

6. Fabricate preform set Nos. 3 and 5 by repeating Steps 1, 2, 3, 4, and 5.

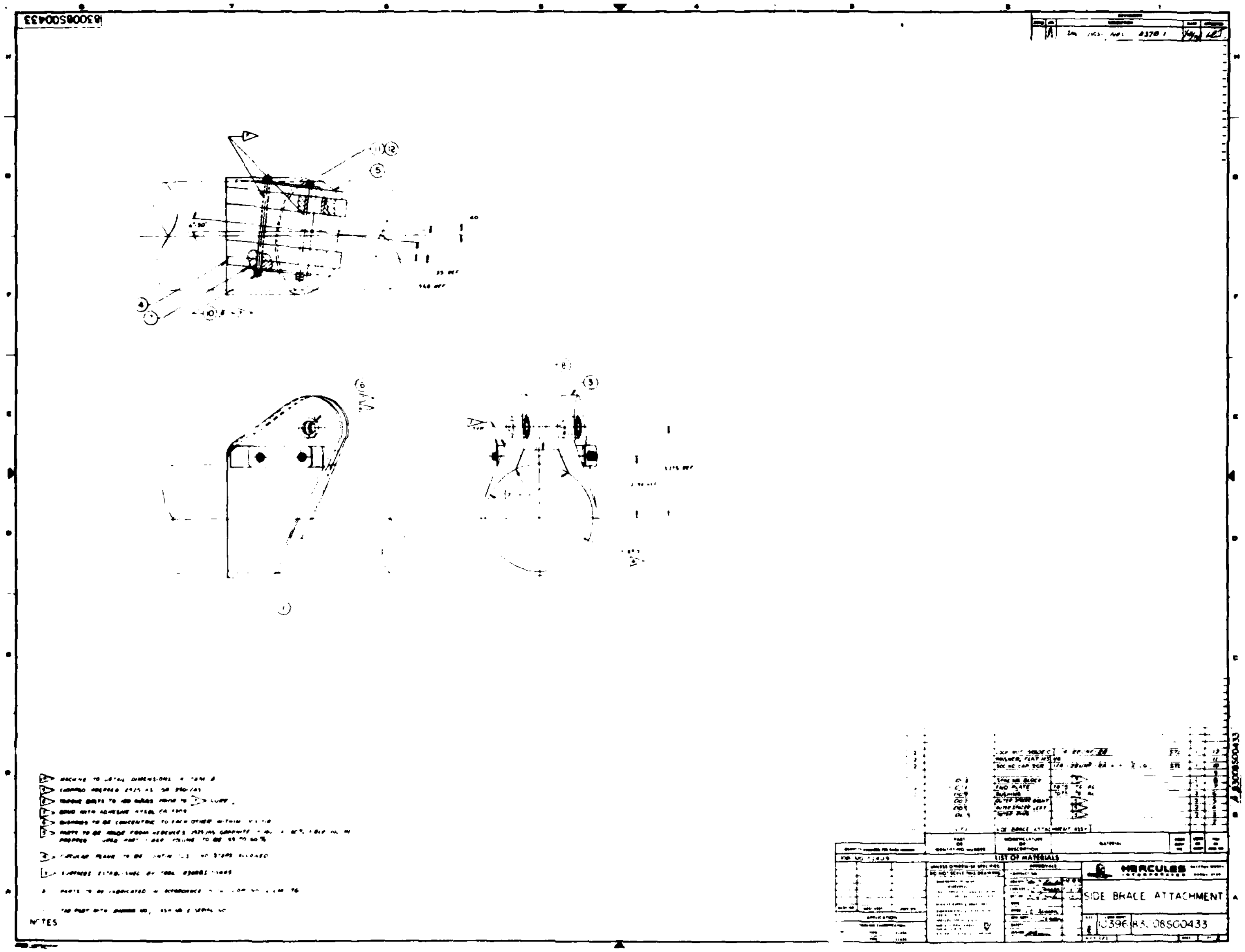


Figure II-19. Side Brace Attachment, Drawing 83008S00433

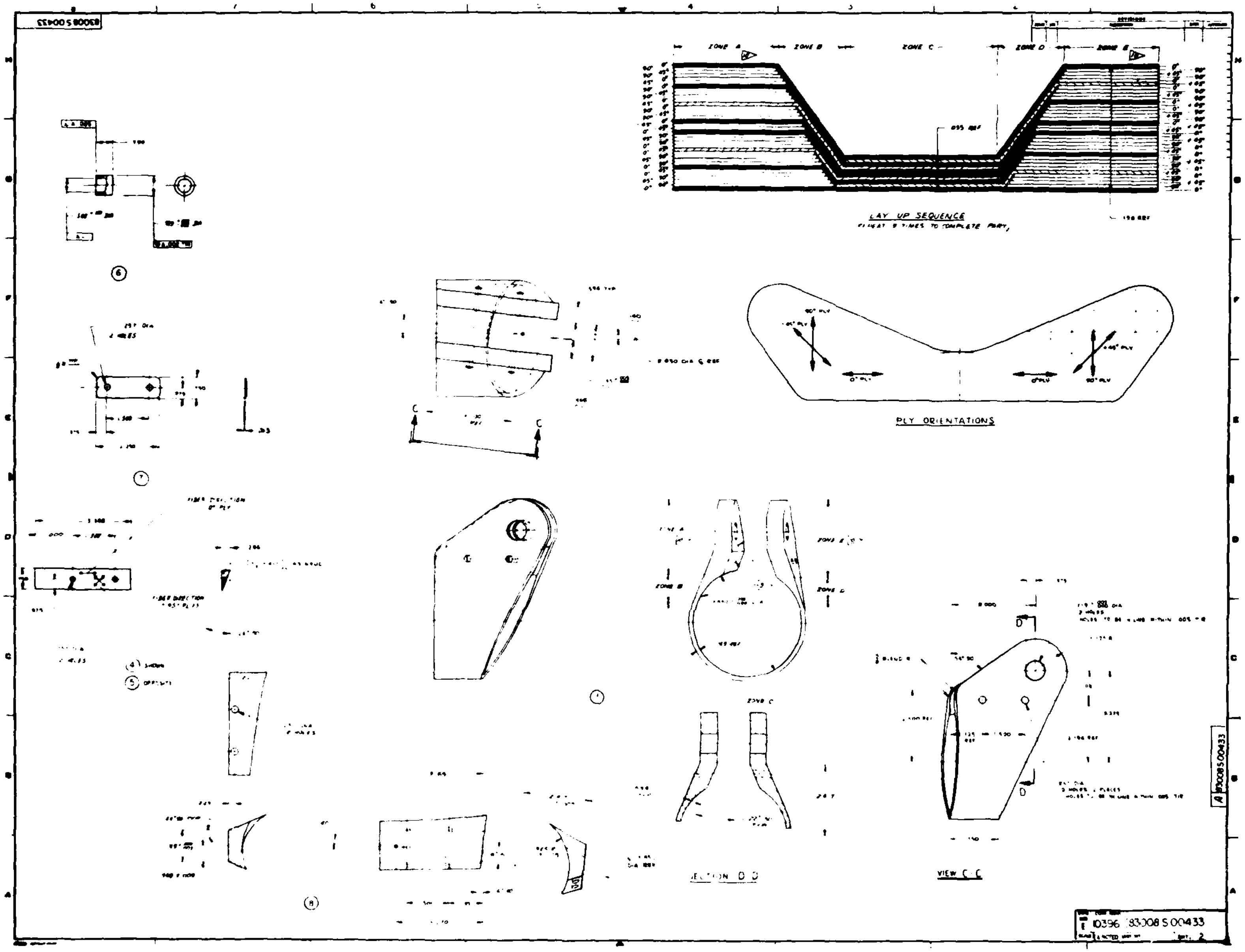


Figure II-20. Side Brace Attachment, Drawing 83008S00433

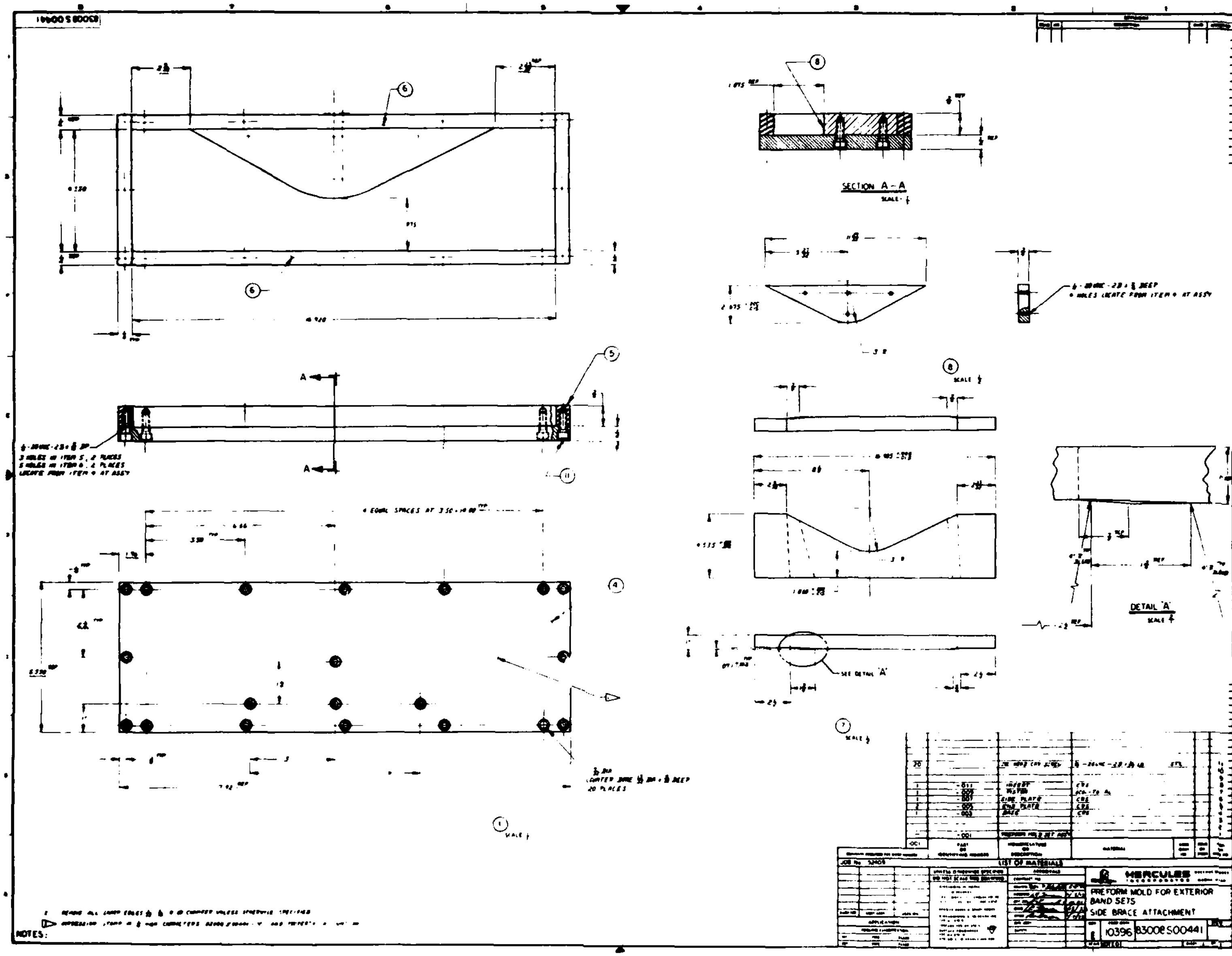


Figure II-21. Exterior Band Set Mold, Side Brace Attachment, Drawing 83008S00441

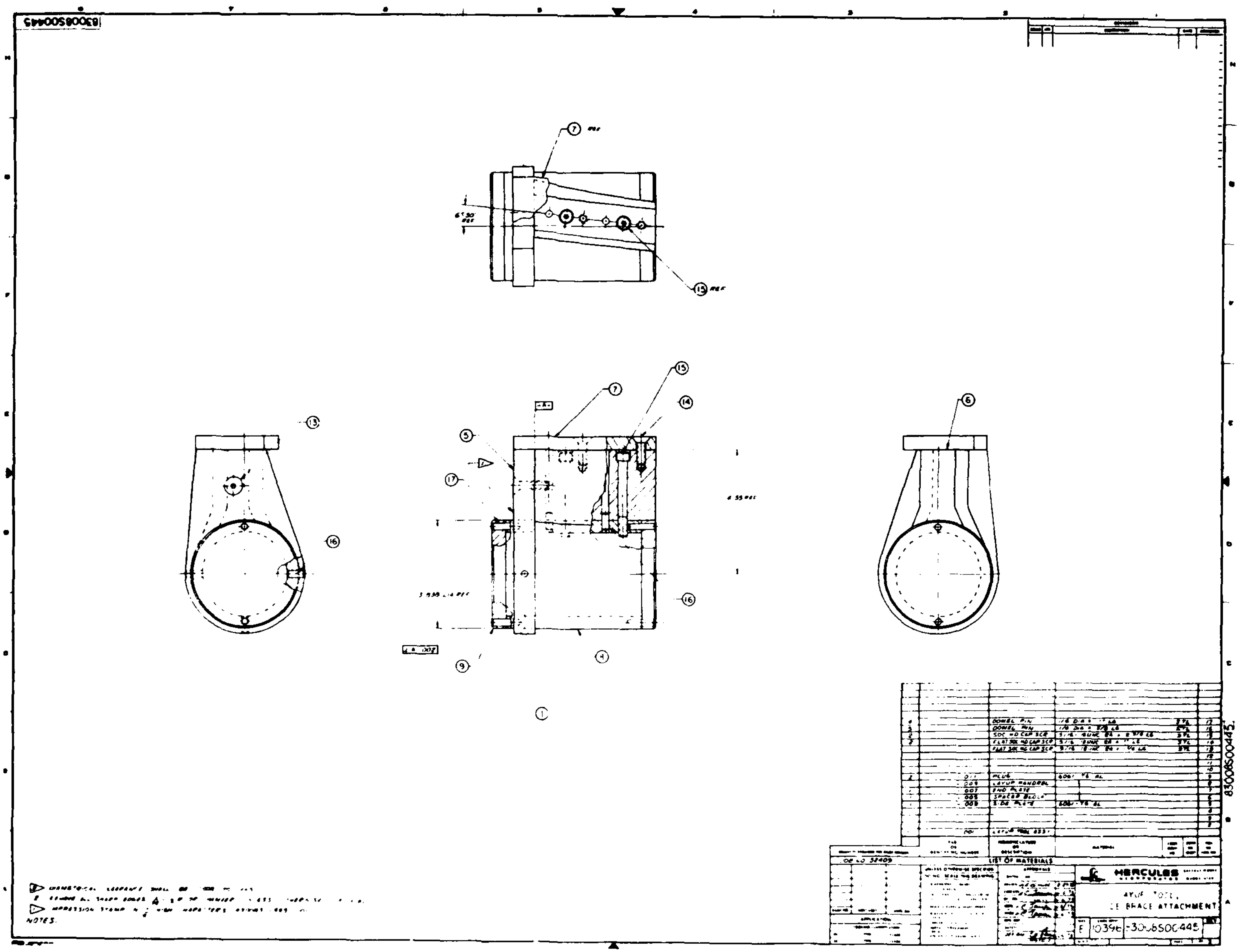


Figure II-22. Layup Tool, Side Brace Attachment, Drawing 83008S00445

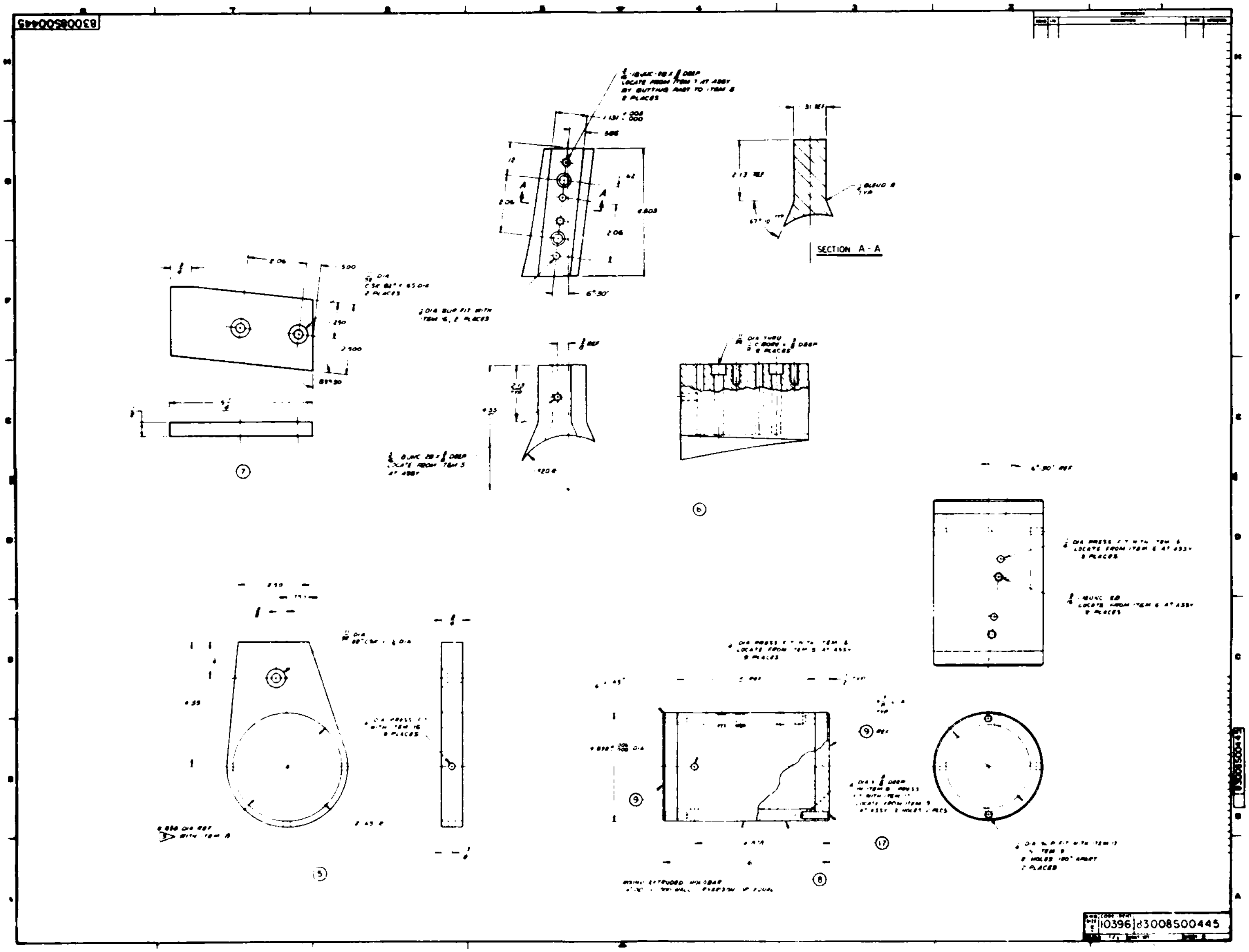


Figure II-23. Layup Tool, Side Brace Attachment, Drawing 83008S00445

AD-A129 206 GRAPHITE COMPOSITE LANDING GEAR COMPONENTS VOLUME II 3/3
TECHNICAL APPENDICES(U) HERCULES INC MAGNA UT BACCHUS
WORKS L C JENSEN ET AL. JUN 77 AFFDL-TR-77-20-VOL-2
UNCLASSIFIED F33615-72-C-1725 F/G 1/3 NL

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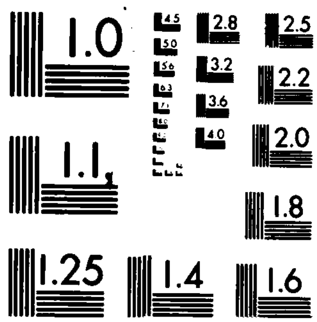
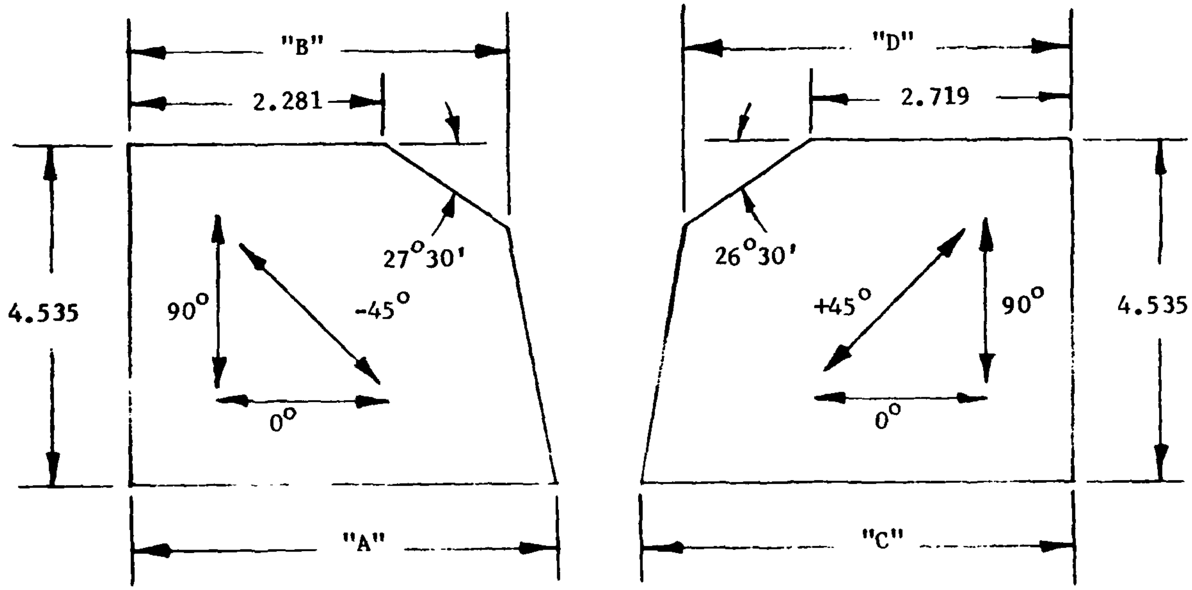


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Ply No.	Left Side			Right Side		
	Length A	Length B	Orientation	Length C	Length D	Orientation
1	Full Length		0^o	Full Length		0^o
2	5.00	4.17	90^o	4.04	4.41	90^o
3	4.90	4.06	-45^o	3.96	4.34	$+45^o$
4	4.81	3.96	90^o	3.88	4.26	90^o
5	4.72	3.85	0^o	3.80	4.19	0^o
6	4.62	3.75	-45^o	Butt to Ply 2 on Left		$+45^o$
7L-11R	Full Length		0^o	Full Length		0^o
7R	--	--	--	3.72	4.11	0^o
8	4.53	3.64	90^o	3.64	4.04	90^o
9	4.44	3.54	-45^o	3.56	3.96	$+45^o$
10	4.34	3.44	90^o	3.48	3.88	90^o
11L	4.25	3.33	0^o	--	--	--
12	Butt to Ply 12 on Right		-45^o	3.40	3.81	$+45^o$
13	4.15	3.23	0^o	3.32	3.73	0^o
14	4.06	3.12	90^o	3.24	3.66	90^o
15	3.97	3.02	-45^o	3.16	3.58	$+45^o$
16	3.87	2.91	90^o	3.08	3.51	90^o
17	Full Length		0^o	Full Length		0^o
18	3.78	2.81	-45^o	3.00	3.43	$+45^o$

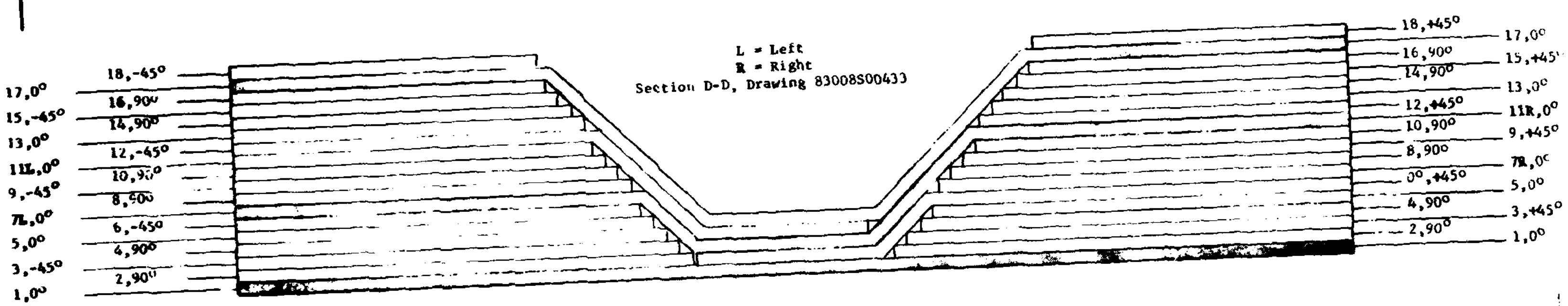
TABLE II-VI

EXTERIOR BAND SETS, SIDE BRACE ATTACHMENT
SETS NO. 1, 3 AND 5, PLY LENGTH VERSUS ORIENTATION



Cutting Pattern
Sets 1, 2, 3, 4, 5 and 6

Figure II-24



Side Brace Attachment
Sets No. 1, 3 and 5
Layup Sequence

Figure II-25

7. Repeat Steps 1 and 2.

8. Cut out and lay up preform set No. 2 in the mold. The orientation, length and ply number within the set are given in Table II-VII. The cutting pattern and layup sequence for the set are shown in Figures II-24 and II-25.

9. Repeat Steps 4 and 5.

10. Fabricate preform sets Nos. 4 and 6 by repeating Steps 1, 2, 8, 4 and 5.

B. Acute corner preform

1. Due to the sharp angle formed by the 6°30' requirement, the layup mandrel requires an "acute corner preform" to preclude wrinkling of the exterior band sets during cure. The location of this preform on the layup mandrel is shown in Figures II-27 and II-28.

2. Obtain a flat metal surface at least 2 in. x 5 in.

3. Clean surface with MEK.

4. Cut out and lay up on the flat surface an "acute corner preform". The orientation, length and ply number within the set are given in Table II-VIII. The cutting pattern and layup sequence for the preforms are shown in Figure II-29.

6. After plies are laid up as in Figure II-29, place the preform assembly against the mold as shown in Figures II-27 and II-28 with ply No. 17 against the crease of the angle of the mold.

7. Place TX-1040 cloth over the preform and place a vacuum bag over the assembly.

8. While under vacuum, place the assembly in the oven at 200°F for 10 minutes.

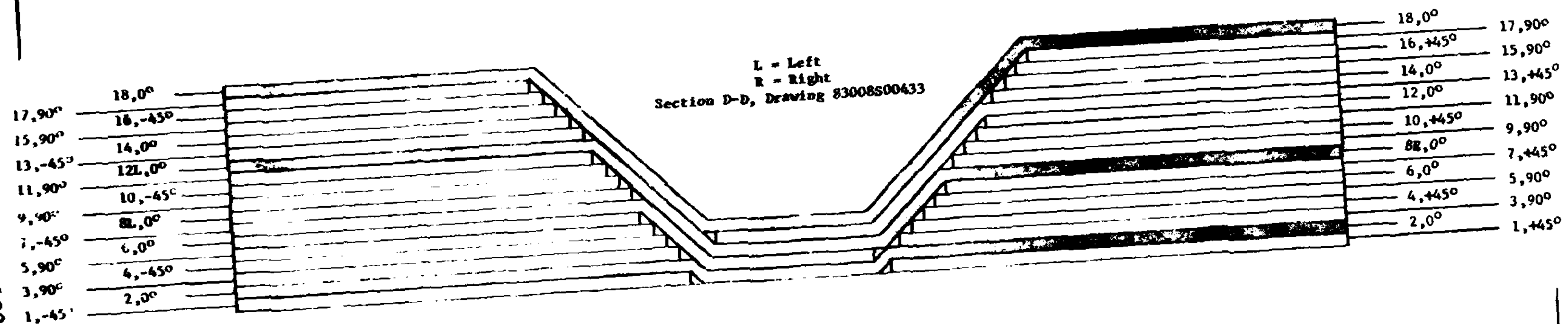
9. Remove from oven and cool down while maintaining vacuum.

10. Disassemble vacuum bag and TX-1040 and remove preform. Trim the preform to a blend shape with the mold surfaces with sandpaper. This blend shape should form a smooth transition between the straight side and cylinder portion of the mandrel.

Ply No.	Left Side			Right Side		
	Length A	Length B	Orientation	Length C	Length D	Orientation
1	5.00	4.17	-45^{o}	4.04	4.41	$+45^{o}$
2	Full Length		0^{o}	Full Length		0^{o}
3	4.90	4.06	90^{o}	3.96	4.34	90^{o}
4	4.81	3.96	-45^{o}	3.88	4.26	$+45^{o}$
5	4.72	3.85	90^{o}	3.80	4.19	90^{o}
6	4.62	3.75	0^{o}	3.72	4.11	0^{o}
7	Butt to Ply 3 on Right		-45^{o}	3.64	4.04	$+45^{o}$
8L	4.53	3.64	0^{o}	--	--	--
8R-12L	Full Length		0^{o}	Full Length		0^{o}
9	4.44	3.54	90^{o}	3.56	3.96	90^{o}
10	4.34	3.44	-45^{o}	3.48	3.88	$+45^{o}$
11	4.25	3.33	90^{o}	3.40	3.81	90^{o}
12R	--	--	--	3.32	3.73	0^{o}
13	4.15	3.23	-45^{o}	Butt to Ply 13 on Left		$+45^{o}$
14	4.06	3.12	0^{o}	3.24	3.66	0^{o}
15	3.97	3.02	90^{o}	3.16	3.58	90^{o}
16	3.87	2.91	-45^{o}	3.08	3.51	$+45^{o}$
17	3.78	2.81	90^{o}	3.00	3.43	90^{o}
18	Full Length		0^{o}	Full Length		0^{o}

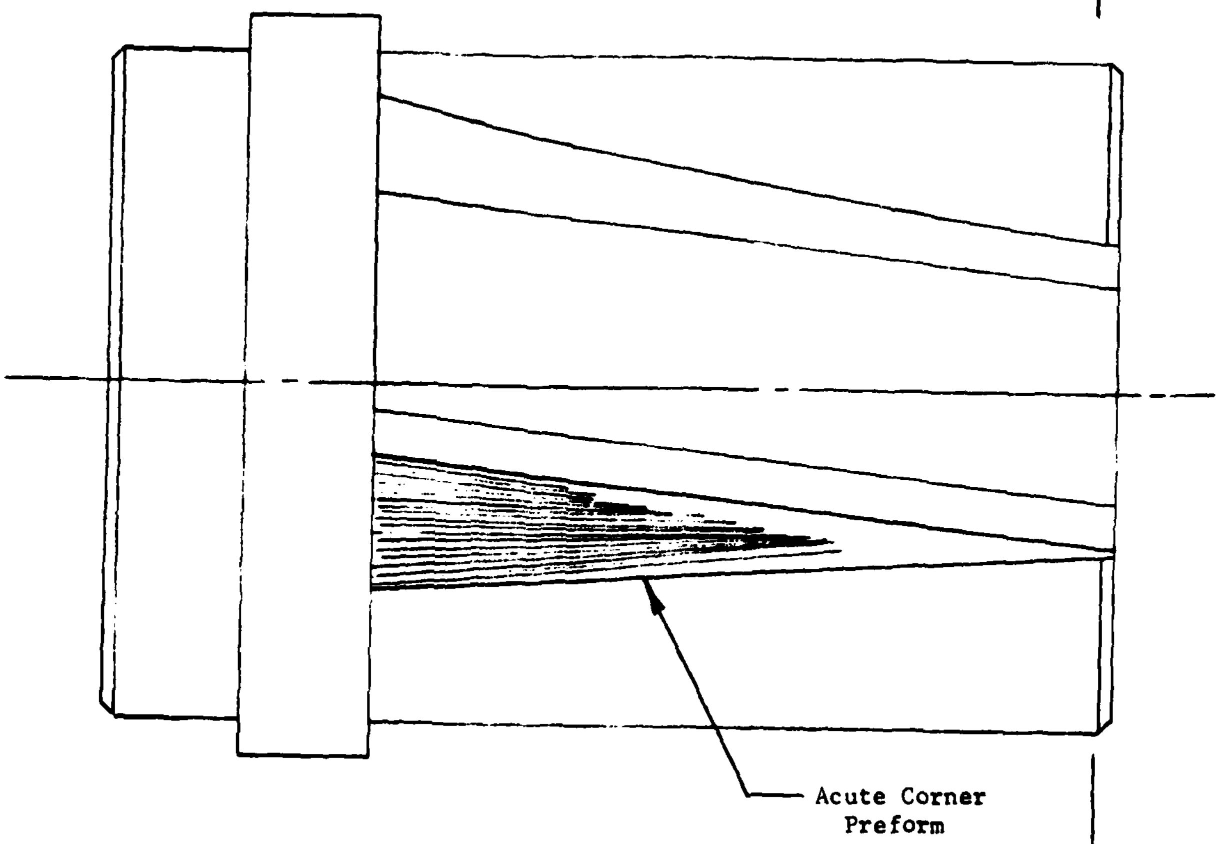
TABLE II-VII

EXTERIOR BAND SETS, SIDE BRACE ATTACHMENT
SETS NO. 2, 4 AND 6, PLY LENGTH VERSUS ORIENTATION



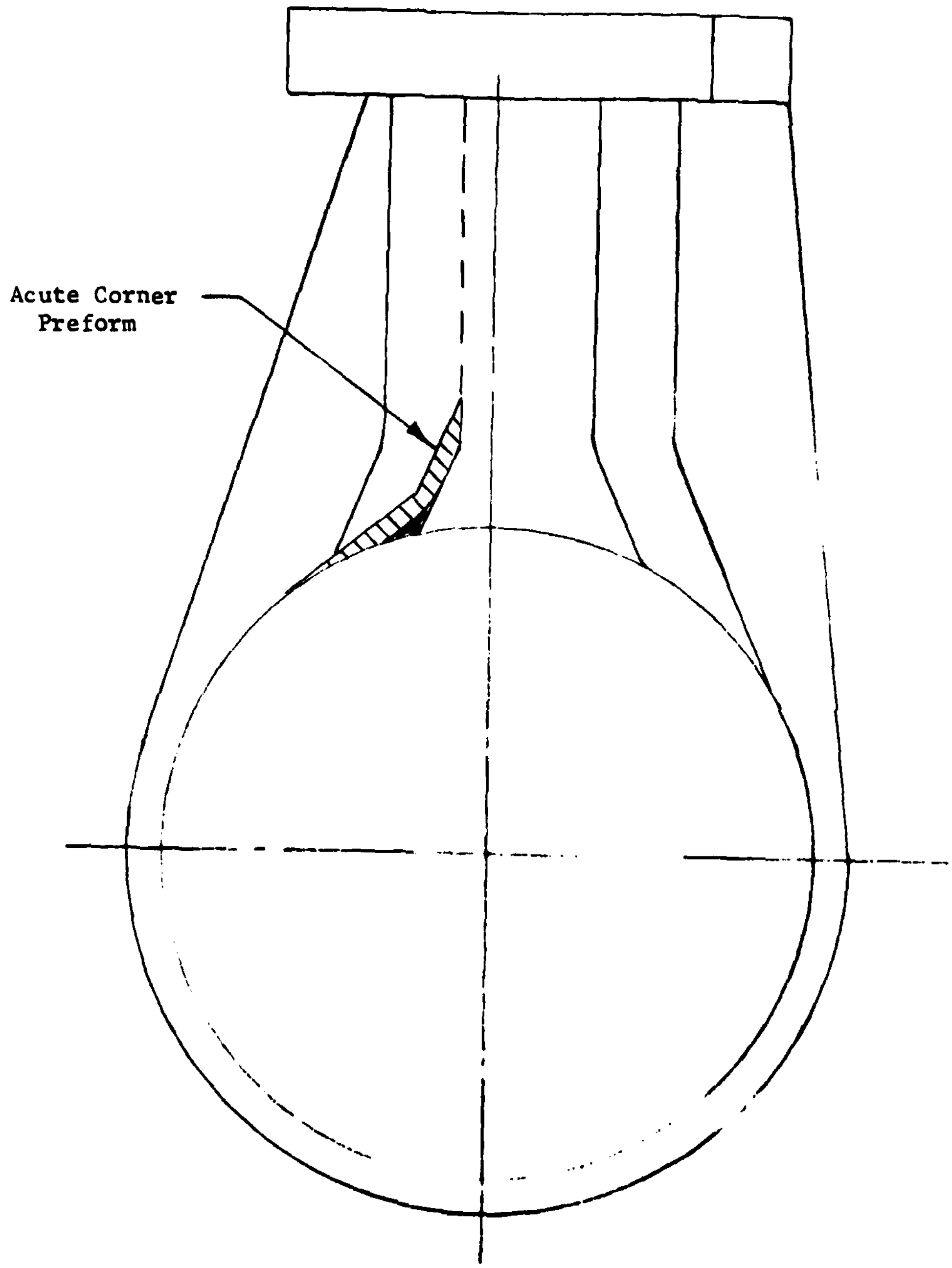
Side Brace Attachment
Sets No. 2, 4 and 6
Layup Sequence

Figure II-26



Top View Position
of
Acute Corner Preform

Figure II-27

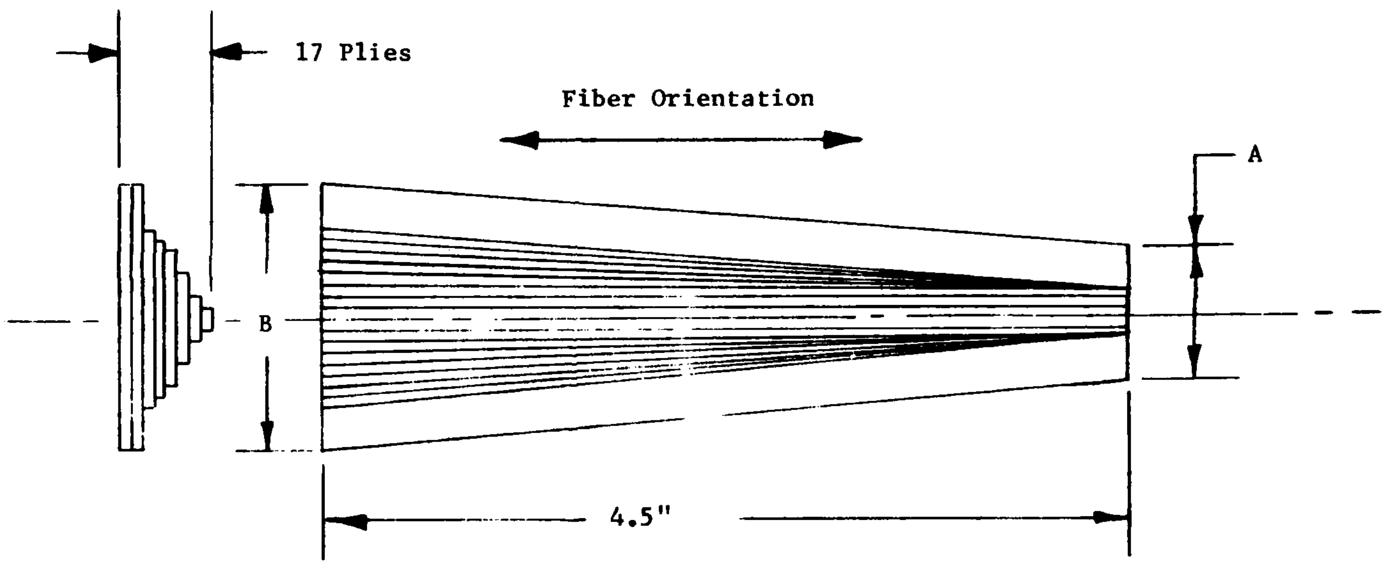


End View Position
of
Acute Corner Preform
Figure II-28

Ply No.	Length "A"	Length "B"
1	0.75	1.50
2	0.75	1.50
3	0.25	1.00
4	0.25	0.90
5	0.25	0.80
6	0.25	0.70
7	0.25	0.60
8	0.20	0.50
9	0.20	0.40
10	0.20	0.35
11	0.15	0.30
12	0.15	0.25
13	0.15	0.20
14	0.10	0.15
15	0.10	0.10
16	0.10	0.10
17	0.05	0.10

TABLE II-VIII

ACUTE CORNER PREFORM
PLY LENGTH VERSUS ORIENTATION



Cutting Pattern and Layup Sequence
for
Acute Corner Preform

Figure II-29

C. Forming exterior band sets on layup mandrel (Mandrel Drawing 83008S00445)

1. Place layup mandrel in oven and heat to 200°F.

2. Place the "acute corner preform" on the mold as shown in Figures II-27 and II-28.

3. Using the hot mandrel, drape each exterior band set (fabricated in Section A) over the mandrel so that they conform approximately to the shape of the mandrel. This is a rough forming operation so each set will be about the same shape.

D. Final assembly (Mandrel Drawing 83008S00439)

1. Fabricate an exterior aluminum sheet metal (.050 in.) caul plate that will conform to the outside dimensions of the cured band sets. Refer to Drawing 83008S00433 for dimensions.

2. Heat the layup mandrel to 200°F and place the "acute corner preform" in its proper place (Step C2).

3. Place exterior band set No. 1 in position (see Figure II-30) and sequentially add bad sets 2, 3, 4, 5 and 6.

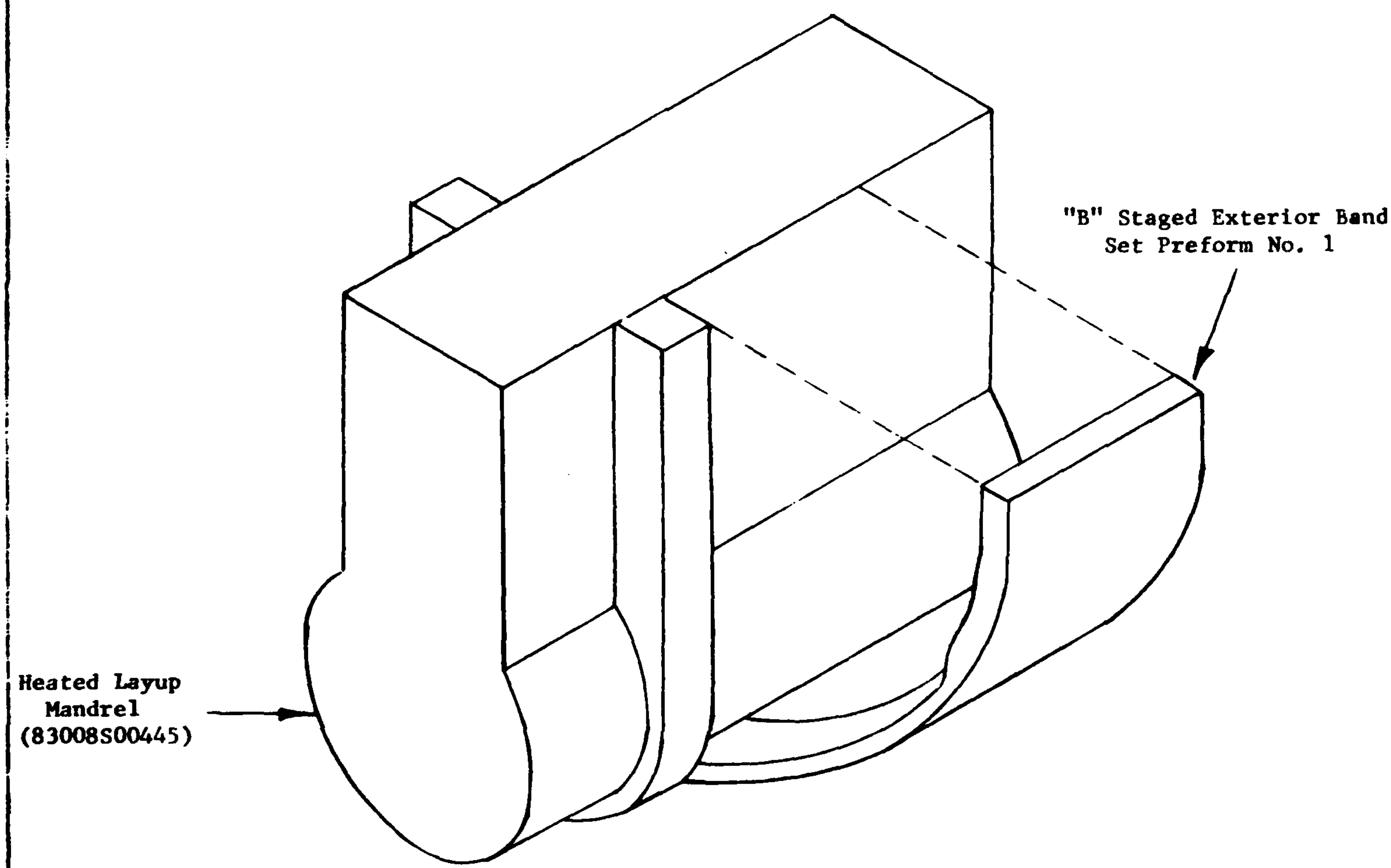
4. Place the caul plate over band set No. 6.

5. Wrap the assembly with TX-1040 release fabric.

6. Wrap this assembly with 12 end glass roving using the No. 21 Winding Machine to rotate the mandrel. Set the torque motor at 70 units to apply proper roving tension.

7. Cool the assembly and remove the glass roving, TX-1040 and caul plate.

8. Trim excess prepreg at top of mandrel and place end plate (Item 7 of Drawing 83008S00445) on mandrel.



Side Brace Attachment Preform Layup

Figure II-30

E. Final cure

1. Replace caul plate and TX-1040 and wrap assembly with 12 end glass roving.

2. Install vacuum bag over this assembly and cure in autoclave.

3. Cure cycle:

   a. Hold vacuum throughout cycle.

   b. Raise temperature 3°/minute to 250°F.

   c. Apply 100 psi at 200°F level.

   d. Hold at 250°F for 4 hours.

   e. Raise temperature at 3°/minute to 300°F.

   f. Hold for 1 hour at 300°F and 100 psi.

   g. Cool down with 100 psi pressure to room temperature (or 150°F maximum).

F. Spacing block fabrication (Item 8 of Drawing 83008S00433)

1. Cut up 5 lbs of 3501/AS prepreg (.005 in. thick) into 1/2 in. x 1/2 in. pieces.

2. Using a standard 4.75 in. diameter slug mold, pack the cavity with 5 lbs of chopped 3501/AS prepreg.

3. Place piston in mold and place assembly in press.

4. Raise temperature to 250°F and apply 2000 psi for 1/2 hour.

5. Raise temperature to 350°F and apply 2000 psi for 2 hours.

6. Cool down and strip billet from mold.

7. Machine billet to configuration of Item 8 of Drawing 83008S00433.

3.0 Inner Cylinder

The inner cylinder is shown on Drawing LCJ37001 (Figure II-31) and was fabricated on a solid aluminum mandrel as shown on Drawing LCJ3002 (Figure II-32). Slit 3501-5/AS prepreg tape was used with the following procedure to fabricate this component.

3.1 Inner Cylinder Fabrication Process

A. Cylinder Wall Layup

1. Clean mandrel (LCJ370002) with Alcanox cleaner and water and allow to dry thoroughly.

2. Apply Frekote #33 release agent to mandrel and bake in 350^{o} oven for 1 hour.

3. Place mandrel in winding machine.

4. Begin layup in Zone A (Figure II-33) by fitting ply No. 1 of Table II-IX (+45^{o}) to mandrel. All angle plies will continue spirally around the mandrel for the full length of the zone. All tape edges shall be built jointed. Make sure all plies are against the shoulder of the mandrel.

5. Compact with overwind material.

6. Lay up Ply No. 2, Table II-IX (-45^{o}) in Zone A (Figure II-33).

7. Apply bleeder overwrap material and overwind with tension control set at 70 to 80 units. Apply low heat with heat gun during overwind.

8. Cool to room temperature before removing compaction material.

9. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor while applying low heat from heat gun. After wrinkles are removed, supervisor approval is required before proceeding to next step.

10. Lay up Plies No. 3 and 4, Table II-IX (0^{o}) in Zone A. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.

11. Repeat steps 7, 8, and 9 for compaction.

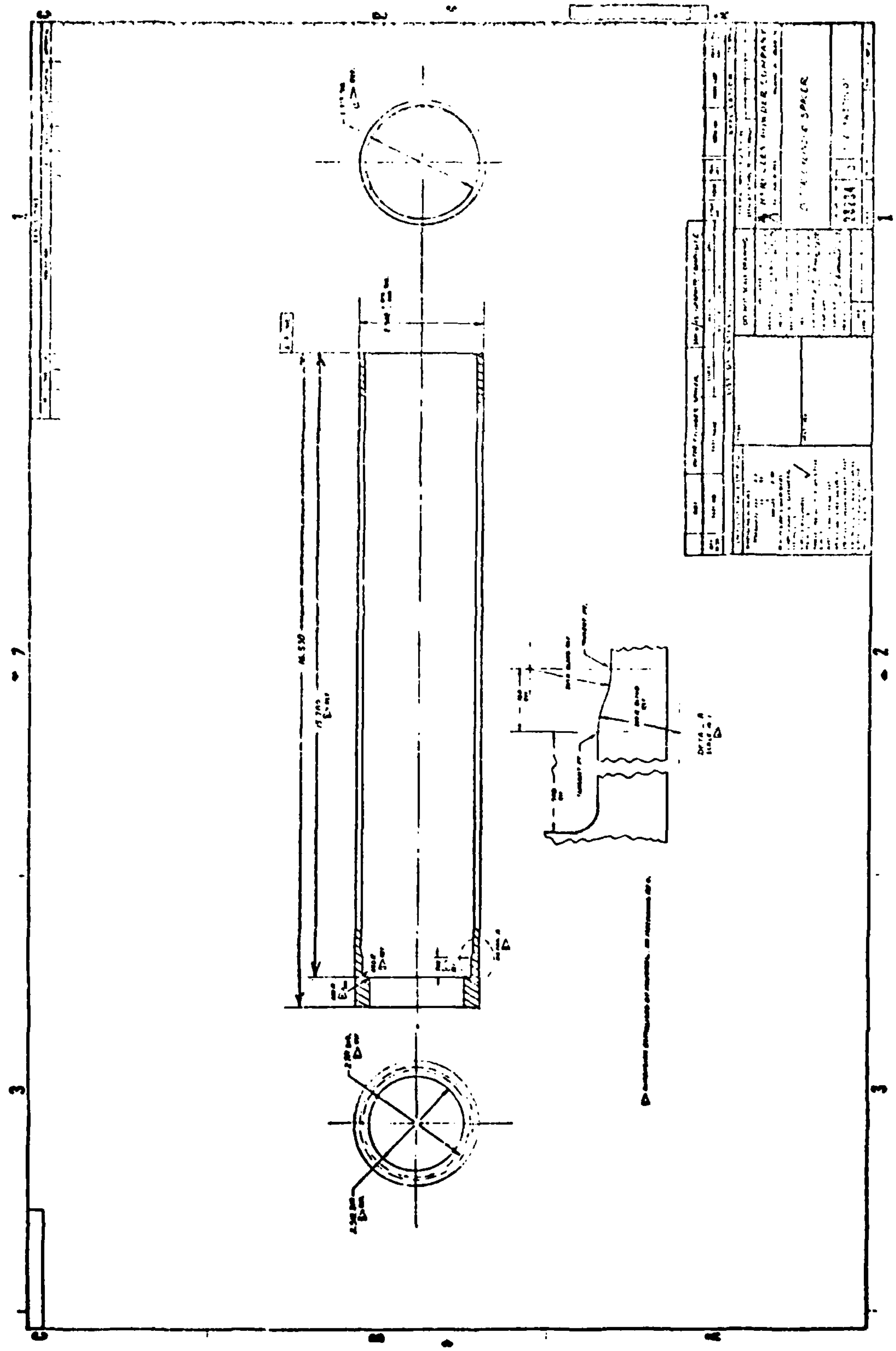


Figure II-31. Inner Cylinder

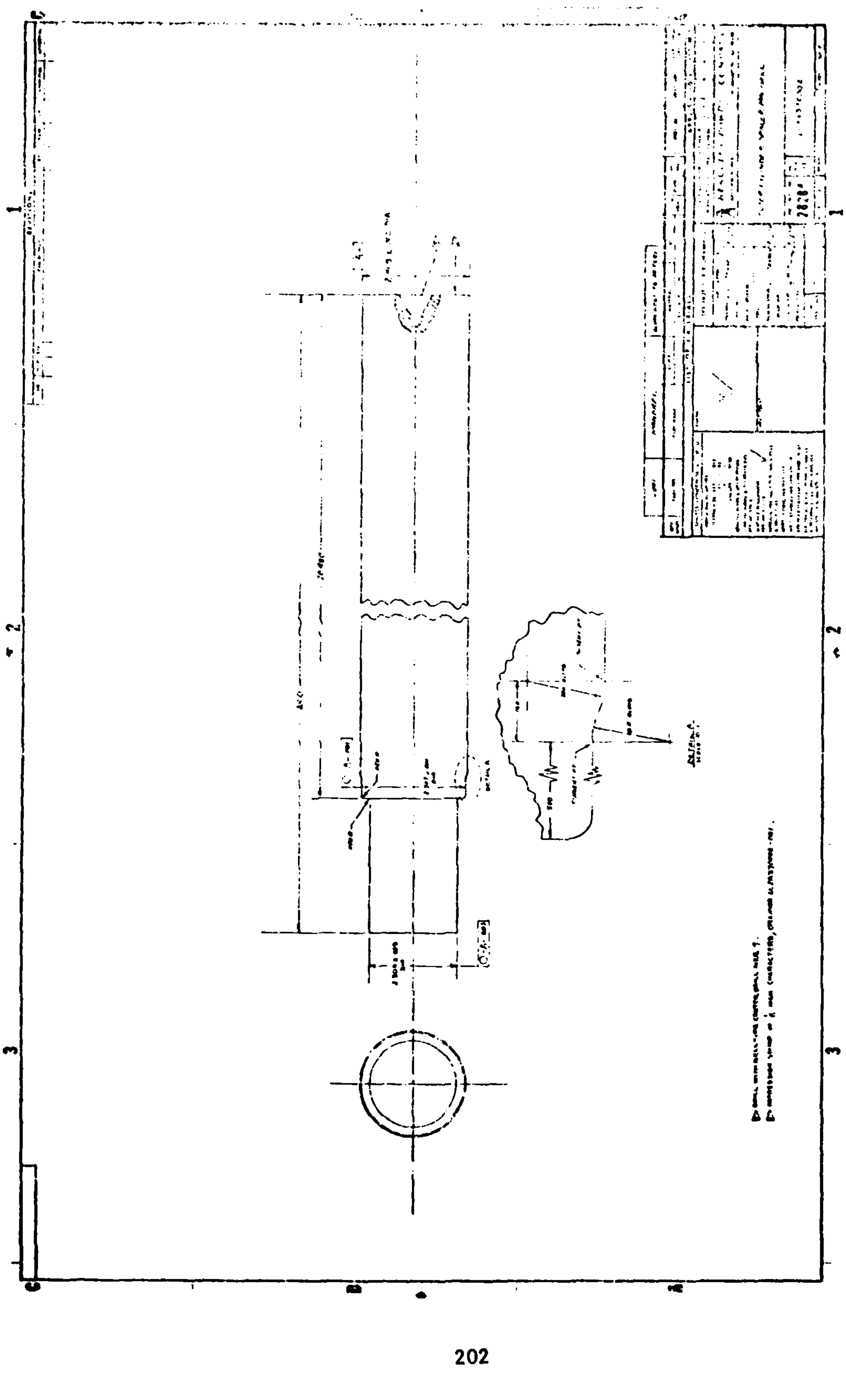


Figure II-32. Inner Cylinder M drel

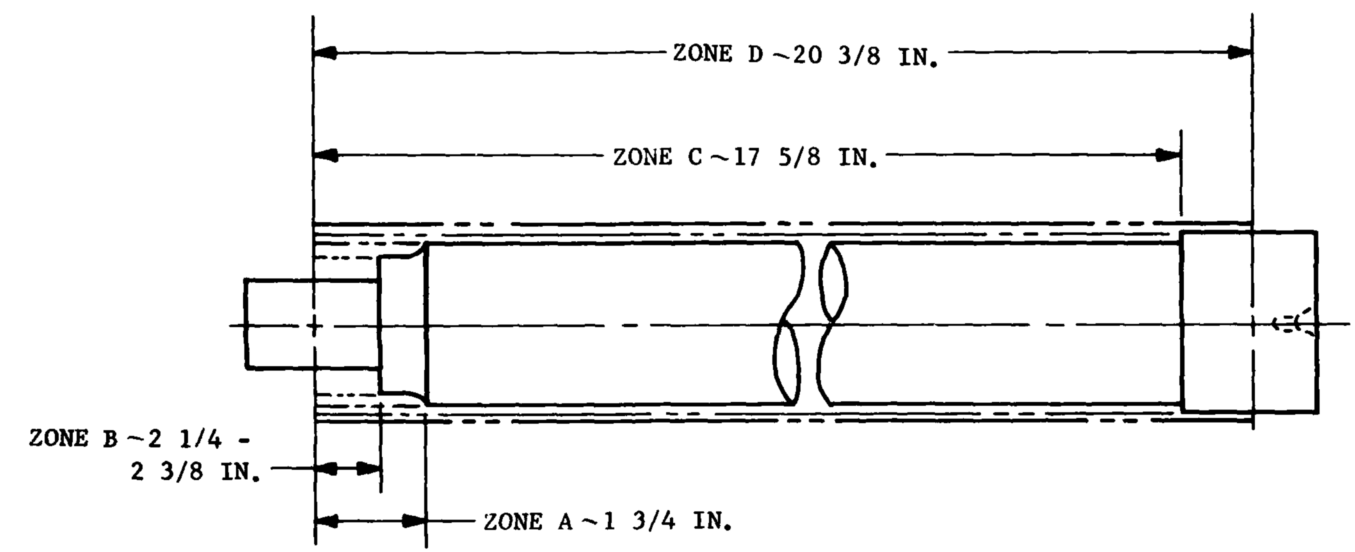


Figure II-33. Layup Zones for Inner Sleeve

TABLE II-IX

PLY NUMBER, ORIENTATION AND DIMENSIONS FOR INNER CYLINDER ZONE A

Ply No.	Orientation Starting At ID	Width Longitudinal	Length Circumferential
1	+ 45°	~ 1-3/4 in.	Cut as required to form a butt joint
2	- 45°	"	"
3	0°	"	"
4	0°	"	"
5	- 45°	"	"
6	+ 45°	"	"
7	0°	"	"
8	0°	"	"
9	+ 45°	"	"
10	- 45°	"	"
11	0°	"	"
12	0°	"	"
13	- 45°	"	"
14	+ 45°	"	"
15	0°	"	"
16	0°	"	"
17	+ 45°	"	"
18	- 45°	"	"
19	0°	"	"
20	0°	"	"
21	- 45°	"	"
22	+ 45°	"	"
23	0°	"	"
24	0°	"	"
25	+ 45°	"	"
26	- 45°	"	"
27	0°	"	"
28	0°	"	"
29	- 45°	"	"
30	+ 45°	"	"
31	0°	"	"
32	0°	"	"
33	+ 45°	"	"
34	- 45°	"	"
35	0°	"	"
36	0°	"	"
37	- 45°	"	"
38	+ 45°	"	"
39	0°	"	"
40	0°	"	"

12. Lay up Plies 5 and 6, Table II-IX ($\mp 45^{\circ}$) in Zone A. Make sure all plies are against shoulder of mandrel.

13. Repeat steps 7, 8, and 9 for compaction.

14. Continue lay up in Zone A in accordance with Table II-IX. Compact per steps 7, 8, and 9 every two plies.

    NOTE: The 40 plies are a calculated number. The number of plies may be adjusted up or down to ensure that the last ply at the inboard edge of Zone A is approximately 0.010 in. above the level of the bare mandrel in Zone B. If adjustment is made, do not change sequence of orientation.

15. Begin layup of cylinder in Zone B by fitting Ply No. 41 of Table II-X ($+45^{\circ}$) to Zone B (Figure II-33) on the mandrel. All angle plies will continue spirally around the mandrel for the full length of the zone. All ply edges shall be butt jointed. Make sure all plies are against the shoulder of the mandrel.

16. Compact with overwind material.

17. Lay up Ply No. 42 of Table II-X (-45°) to Zone B (Figure II-33) on the mandrel.

18. Apply bleeder overwrap material and overwind with tension control set at 70 to 80 units. Apply low heat with heat gun during overwind.

19. Cool to room temperature before removing compaction material.

20. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor while applying low heat from heat gun. After wrinkles are removed, supervisor approval is required before proceeding to next step.

21. Lay up Plies No. 43 and 44, Table II-X (0°) in Zone B. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.

22. Repeat steps 18, 19, and 20 for compaction.

TABLE II-X

PLY NUMBER, ORIENTATION AND DIMENSIONS FOR
INNER CYLINDER ZONE B

Ply No.	Orientation Starting At ID	Width Longitudinal	Length Circumferential
41	+ 45°	Varies from 2-1/4 to 2-3/8 in.	Cut as required to form a butt joint
42	- 45°	"	"
43	0°	"	"
44	0°	"	"
45	- 45°	"	"

23. Lay up Plies No. 45 and 46, Table II-X ($\pm 45^{o}$) in Zone B. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.

24. Repeat steps 18, 19, and 20 for compaction.

25. Continue layups in Zone B in accordance with Table II-X. Compact per steps 18, 19, and 20.

26. Apply porous scrim cloth over entire area of Zone B. Wrap one heavy Armalon ply around mandrel. Overwind with tension control set at 70 to 80 units while applying low heat to prepreg with heat gun. Install thermocouple and place in vacuum bag. Draw vacuum and heat to 200 ± 10^{o} F until excess resin migrates into bleeder. Cool to room temperature under vacuum.

27. Remove bleeder material.

28. Begin layup over Zone C by fitting Ply No. 46 of Table II-XI ($+45^{o}$). All angle plies will continue spirally around the mandrel for the full length of the zone. Ply edges shall be butt jointed. Make sure ends of plies are against shoulder of mandrel.

29. Compact with overwind material.

TABLE II-XI

PLY NUMBER, ORIENTATION AND DIMENSIONS FOR
INNER CYLINDER ZONE C

Ply No.	Orientation Starting At ID	Width Longitudinal	Length Circumferential
46	+ 45°	~ 17-5/8 in.	Cut as required to form a butt joint
47	0°	"	"
48	0°	"	"
49	+ 45°	"	"
50	- 45°	"	"
51	0°	"	"
52	0°	"	"
53	- 45°	"	"
54	+ 45°	"	"
55	0°	"	"
56	0°	"	"
57	+ 45°	"	"
58	45°	"	"
59	0°	"	"
60	0°	"	"

30. Lay up Plies No. 47 and 48, Table II-XI (0^{o}) over Zone C. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.

31. Apply bleeder overwrap and overwind with tension control set at 70 to 80 units. Apply low heat to prepreg with heat gun during overwind.

32. Cool to room temperature before removing compaction material.

33. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor while applying low heat from heat gun. After wrinkles are removed, supervision approval is required before proceeding to next step.

34. Lay up Plies No. 49 and 50, Table II-XI (0^{o}) over Zone C. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.

35. Repeat steps 31, 32, and 33 for compaction.

36. Continue layup in Zone C in accordance with Table II-XI. Compact per steps 31, 32, and 33 every two plies.

37. Begin layup over Zone D by fitting Ply No. 61 of Table II-XII (-45^{o}). All angle plies shall continue spirally around the mandrel over the entire length of the zone. Ply edges shall be butt jointed.

38. Compact with overwind.

39. Lay up Ply No. 62 of Table II-XII ($+45^{o}$) over Zone D.

40. Apply porous scrim cloth over entire area of Zone D. Wrap one heavy Armalon ply around mandrel. Overwind with tension control set at 70 to 80 units while applying low heat to prepreg with heat gun. Install thermocouple and place in vacuum bag. Draw vacuum and heat to 200 ± 10^{o} F until excess resin migrates into bleeder. Cool to room temperature under vacuum.

41. Remove compaction material.

TABLE II-XII

PLY NUMBER, ORIENTATION AND DIMENSIONS FOR INNER CYLINDER, ZONE D

Ply No.	Orientation Starting at ID	Width Longitudinal	Length Circumferential
61	-45^{o}	~20-3/8 in.	Cut as required to form a butt joint
62	$+45^{o}$	"	"
63	0^{o}	"	"
64	0^{o}	"	"
65	$+45^{o}$	"	"
66	-45^{o}	"	"
67	0^{o}	"	"
68	0^{o}	"	"
69	-45^{o}	"	"

42. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor while applying low heat from heat gun. After wrinkles are removed, supervisor approval is required before proceeding to next step.

43. Lay up Plies No. 63 and 64 over Zone D. All ply edges shall be butt jointed.

44. Repeat steps 40, 41, and 42 for compaction.

45. Continue layup in Zone D in accordance with Table II-XII. Compact every two plies per steps 40, 41, and 42.

46. Lay up Ply No. 69, Table II-XII (-45^{o}) over Zone D.

47. Apply porous scrim cloth over entire area of Zone D. Wrap one heavy Armalon ply around mandrel. Overwind with tension control set at 70 to 80 units while applying low heat to prepreg with heat gun. Install thermocouple and install in vacuum bag.

48. Install in autoclave, draw vacuum, and apply pressure. Heat to $250^{\circ} \pm 10^{\circ}$ F. Maintain pressure and vacuum during cooldown to room temperature.

49. Remove compaction material.

B. <u>Inner Cylinder Cure</u>

1. Apply porous scrim over entire layup.

2. Overwind using a tension setting of 70 to 80 units while applying low heat with heat gun.

3. Install thermocouple, vacuum line, and vacuum bag.

4. Place in autoclave.

5. Hold vacuum throughout cure cycle

6. Apply 100 psi pressure initially.

7. Raise temperature 3°/minute to 250° F.

8. Hold at 250° F for 1 hour

9. Raise temperature at 3°/minute to 300° F.

10. Hold for 1/2 hour at 300° F.

11. Raise temperature at 3°/minute to 350° F.

12. Hold for 2 hours at 350° F.

13. Cool down to 150° F under pressure.

14. Remove from autoclave at 150° F or below.

15. Remove from mandrel.

16. Postcure for 2 hours at 400° F.

4.0 Outer Cylinder Trunnion

The outer cylinder/trunnion is shown in Figure II-34. Fabrication was performed using the trunnion mandrel assembly seen in Figures II-35 and II-36. Using 3501-5/AS prepreg tape, the following fabrication procedure was used.

4.1 Outer Cylinder/Trunnion Fabrication Process

A. Outer Cylinder/Trunnion Wall Layup

1. Thoroughly clean the mandrel with Alconox and water. Allow to dry.

2. Apply Frekote No. 33 release agent and bake at 350^{o} F for 1 hour. Cool to room temperature.

3. Brush a coat of 3501-5 resin on the mandrel and air dry for approximately 20 minutes.

4. Using 3-inch tape, start the layup of Ply No. 1, Figure II-37 (-45^{o}). The layup will start at the chuck end of the outer cylinder and continue to the beginning of the ramp area. Ply will be completed with edges of tape butt jointed. Use heat gun to hold tape in place, if required.

5. Starting where the outer cylinder layup stopped, continue -45^{o} layup for the ramp area and flat surfaces. Cut the 3-inch tape as required to maintain 45^{o} angle on the ramp area. At the point where the cylinder layup stops and the ramp and flat surface layups start, maintain 1/4 inch overlap throughout. Stagger this overlap on future plies. (Figure II-38.)

6. Lay up Ply No. 2 ($+45^{o}$) by repeating steps 4 and 5, except Ply No. 2 is 90^{o} from Ply No. 1 (Figure II-38).

7. Lay up Ply No. 3a (0^{o}) using prepreg slit to a width that can be easily worked without wrinkling (approximately 1/4 inch or wider depending on location). Layup this ply so that "B" and "C" dimensions of Figure II-39 and Table II-XIII are satisfied.

8. Finish Ply No. 3a (0^{o}) in the flat areas by laying over ply of 3 inch tape or wider per Figure II-39 and Table II-XIII.

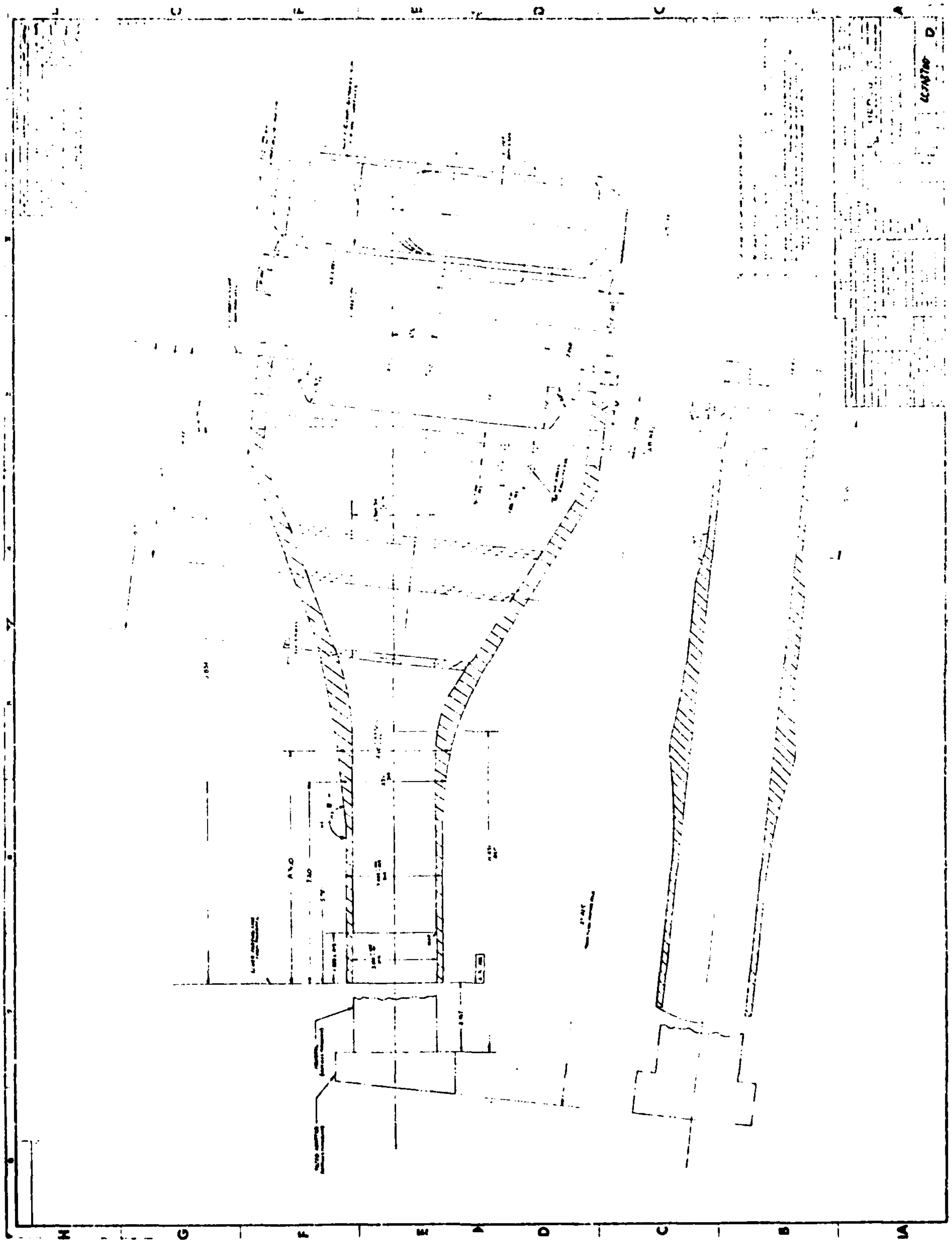


Figure II-34. Outer Cylinder/Trunnion

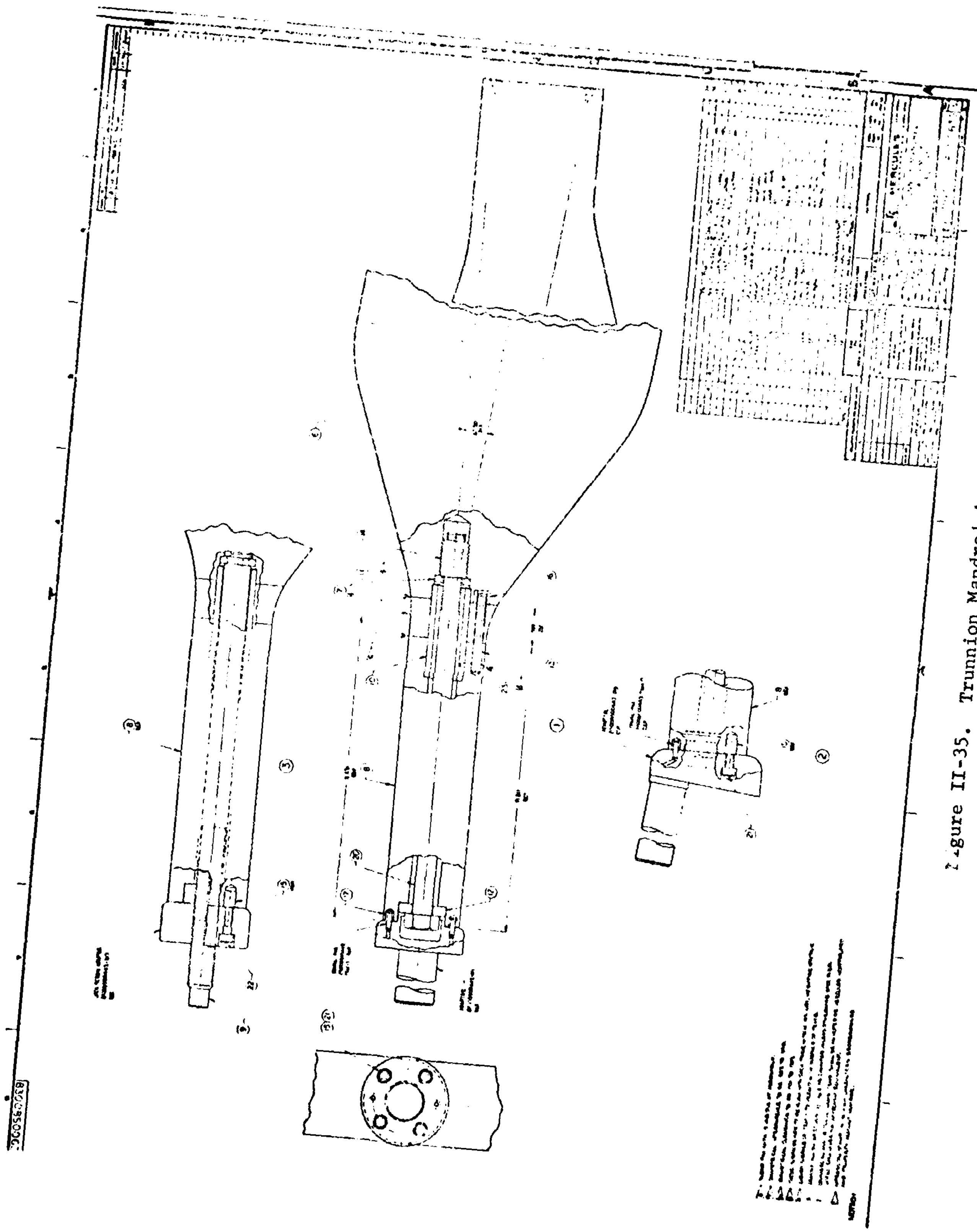


Figure II-35. Trunnion Mandrel Assembly

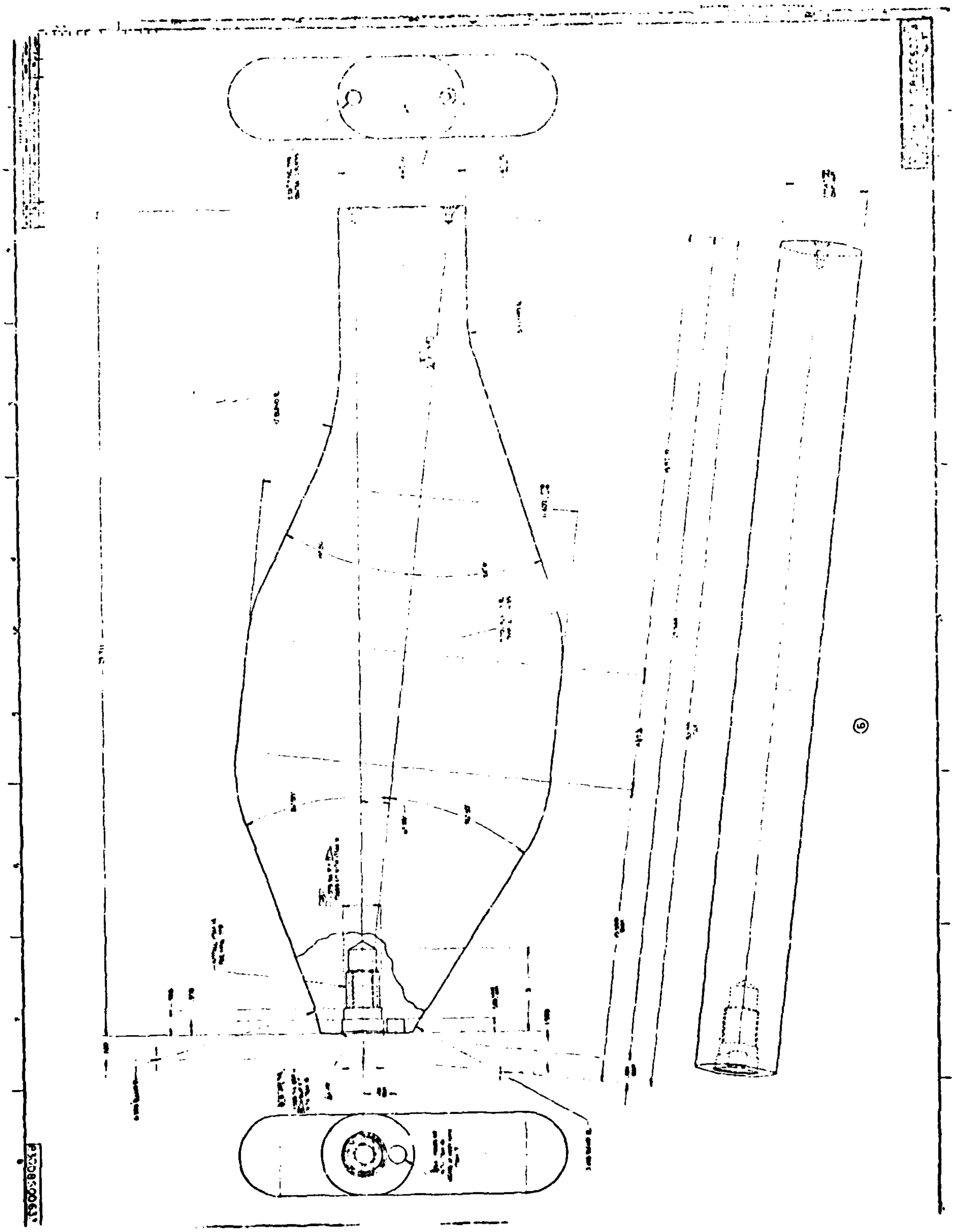


Figure II-36. Trunnion Mandrel Assembly

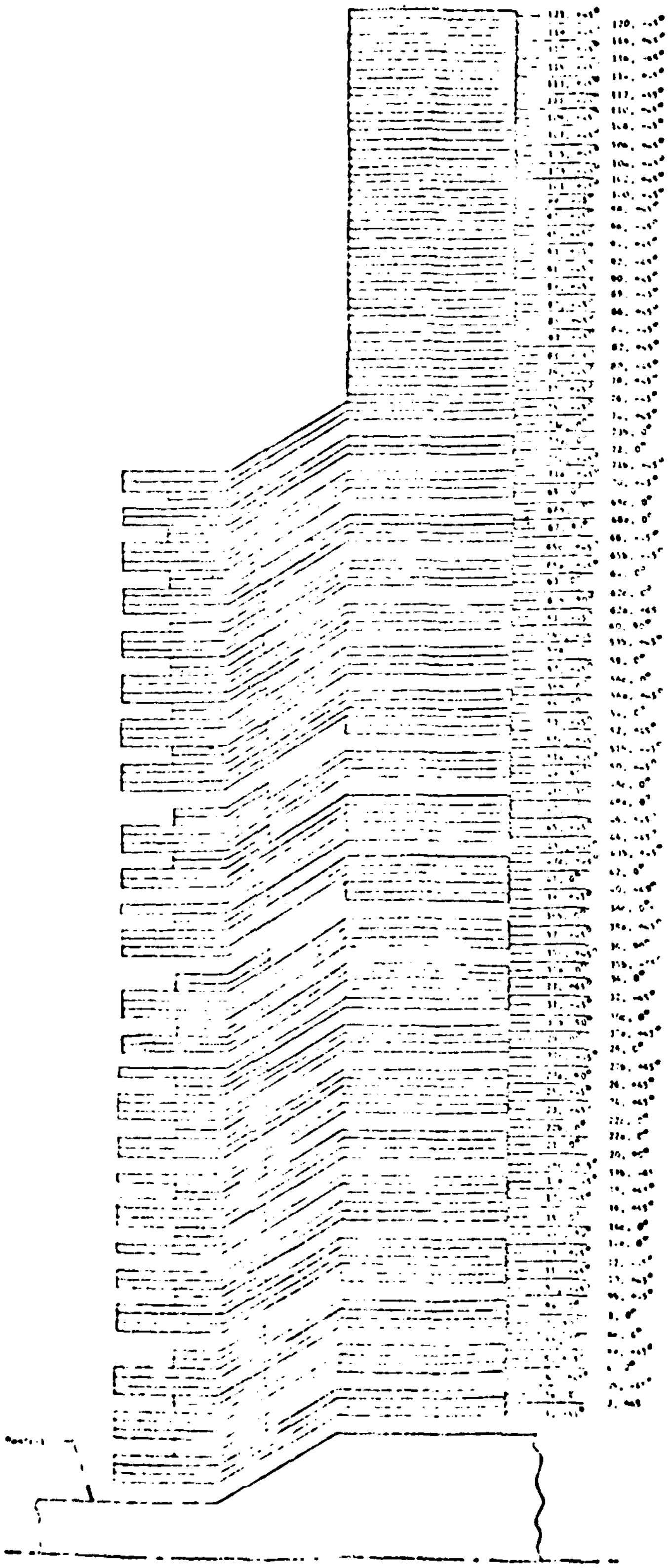
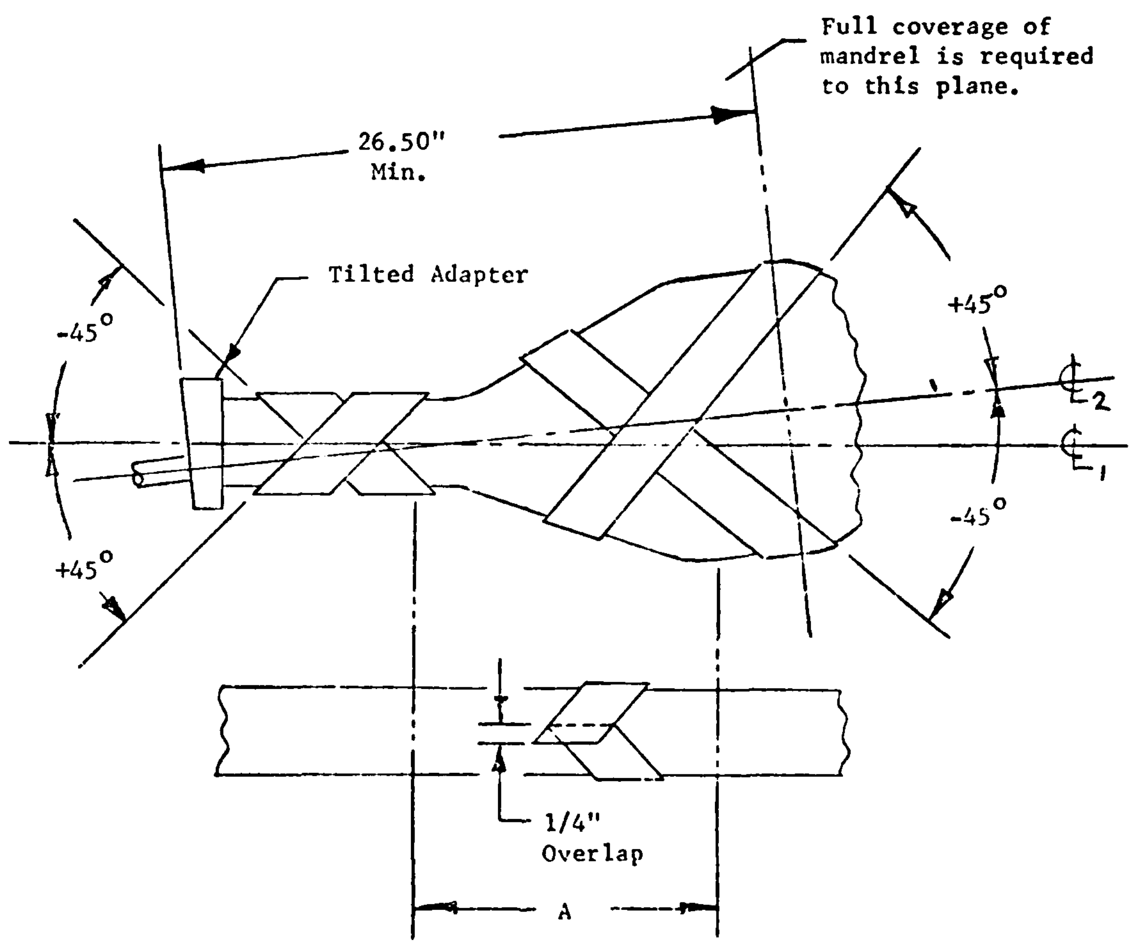


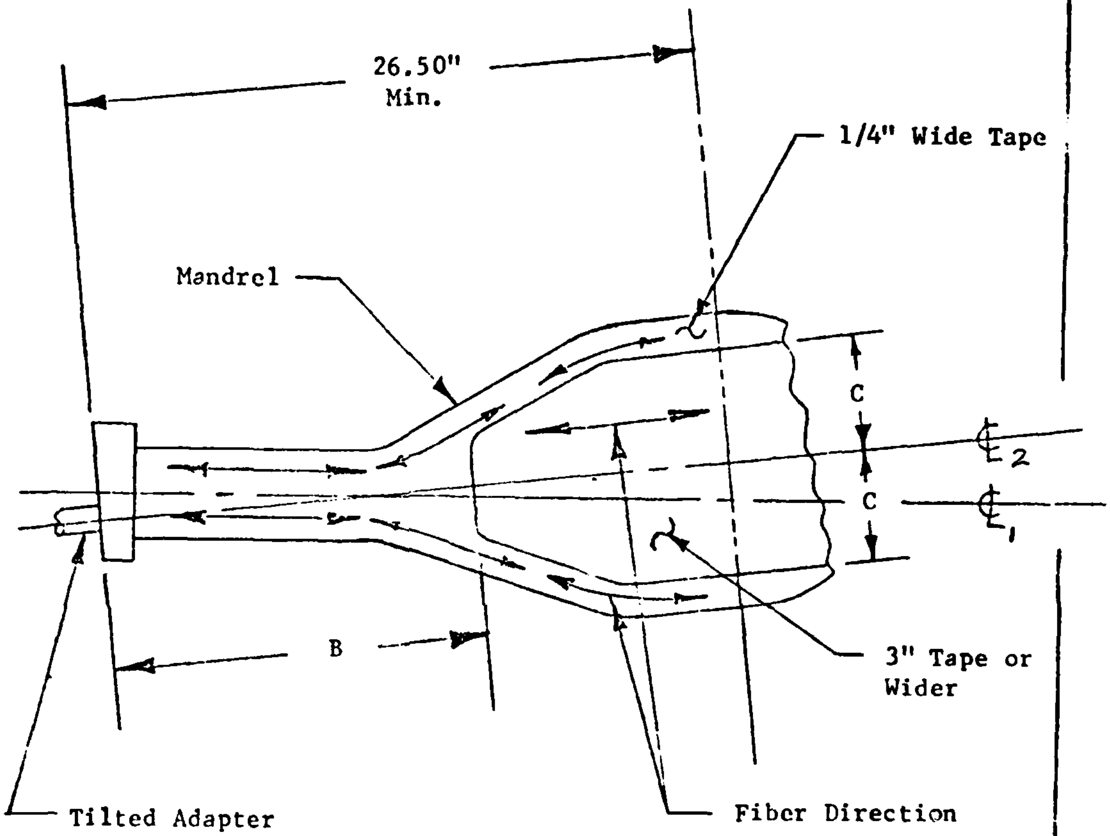
Figure II-37. Trunnion Lay Up Sequence



To maintain 45° angle in Zone A, cut 3" tape as required. Overlap tape as shown.

Trunnion Layup Detail
for
±45° Plies, Full Coverage

Figure II-38



Layup Procedure

1. Lay slit tape on mandrel until the C dimension is satisfied.
2. Lay slit tape on mandrel until the B dimension is satisfied.
3. Lay 3" or wider tape (1 ply) in area shown in above sketch.

Trunnion Layup Detail
for
0° Plies

Figure II-39

TABLE II-XIII

0^{o} PLIES

Ply No.	"B" Dimension (in.)	"C" Dimension (in.)
3a	15.15	3.00
4	15.15	3.00
8	14.45	4.12
9	14.45	4.12
14a	15.05	3.16
21	14.35	4.28
22a	14.35	4.28
28	14.95	3.32
29	14.95	3.32
34	14.25	4.44
35a	14.25	4.44
41	14.85	3.48
42	14.85	3.48
47	15.15	4.60
48a	15.15	4.60
54	14.75	3.64
55	14.75	3.64
58	14.05	4.76
59a	14.05	4.76
63	14.65	3.80
64	14.65	3.80
68a	13.95	4.92
69	13.95	4.92
72	14.55	3.96
73a	14.55	3.96

9. Lay up Ply No. 36 (-45°) and 3c (+45°) per Figure II-40 using prepreg slit to a width that can be easily worked without wrinkling to meet dimensions "M" and "N" of Table II-XIV. Use heat gun to hold tape in place as required. Trim the tape so that no more than 1/4 inch overlap is obtained. Stagger the overlap on future plies.

10. Lay up Ply No. 4 (0°) by repeating steps 7 and 8 per Figure II-39 and Table II-XIII.

11. Apply a layer of porous scrim cloth and one layer of Machburg cloth over the entire layup. Starting at the bottom of the ramp, wind 90° glass roving on the cylinder section towards the chuck using a tension setting of 70 to 80 units. In the ramp area only, apply double face tape. Starting at the bottom of the ramp, wind 90° glass roving toward the tail stock with a tension setting of 70 to 80 units.

12. Place a thermocouple onto the prepreg, install blue peel, vacuum line, and vacuum bag.

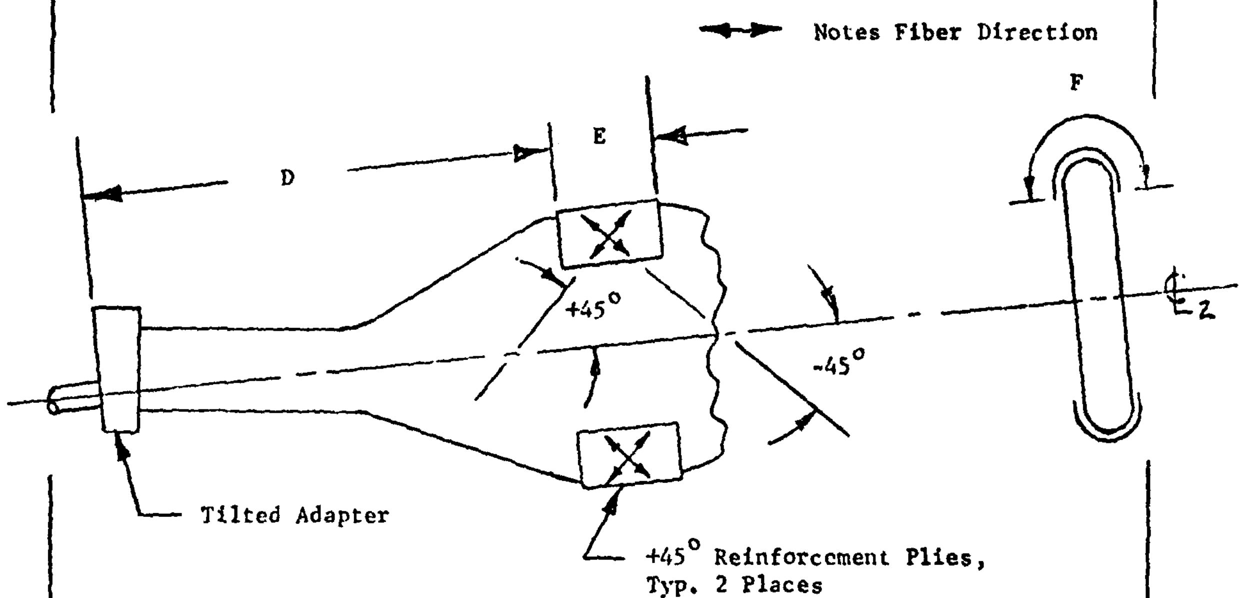
13. Place assembly in autoclave. Heat part to 200 $\pm$ 15° and apply pressure for 20 minutes. Turn off heat and pressure and open autoclave door. Leave vacuum on for a minimum of 12 hours before starting the next step. Record time assembly was placed in and taken out of heat source.

14. Remove compaction materials. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor and heat gun. After wrinkles are removed, supervisor approval is required before proceeding to next step.

15. Lay up Ply No. 5 (+45°) and Ply No. 6 (-45°) by repeating steps 4, 5, and 6.

16. Lay up Plies No. 6b (0°) and No. 6c (0°) per Figure II-41 and Table II-XVI by repeating technique of step 9.

17. Using 1/4 inch wide prepreg, wind ply No. 7 (90°) according to Figure II-42 and Table II-XV. Start at the bottom of the ramp and wind on the cylinder towards the chuck using Centerline No. 1. For the elliptical section, start at the bottom of the ramp and wind towards the tail stock using Centerline No. 2. Tnesion control shall be set at 35 to 40 units.



Trunnion Layup Detail
for
±45° Reinforcement Plies
Figure II-40

TABLE II-XIV

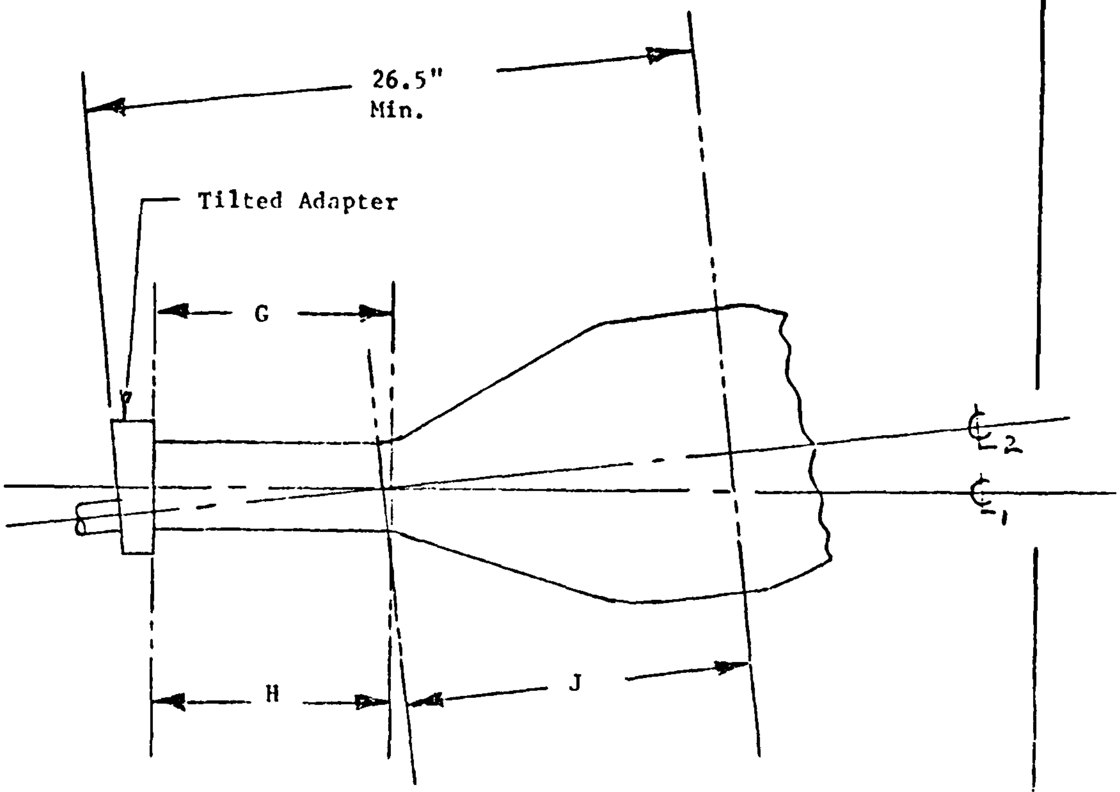
45° REINFORCEMENT PLIES

Ply No.	"D" Dimension (in.)	"E" Dimension (in.)	"F" Dimension (in.)
10	21.15	5.49	6.48
11	21.15	5.49	6.48
17	21.22	5.37	6.31
18	21.22	5.37	6.31
24	21.29	5.25	6.14
25	21.29	5.25	6.14
32	21.36	5.13	5.97
33	21.36	5.13	5.97
39	21.43	5.02	5.80
40	21.43	5.01	5.80
45	21.50	4.89	5.63
46	21.50	4.89	5.63
52	21.57	4.77	5.46
53	21.57	4.77	5.46
76	21.64	4.65	5.29
77	21.64	4.65	5.29
78	21.71	4.53	5.12
79	21.71	4.53	5.12
80	21.78	4.41	4.95
81	21.78	4.41	4.95
82	21.85	4.29	4.78
83	21.85	4.29	4.78
84	21.92	4.17	4.61
85	21.92	4.17	4.61
86	21.99	4.05	4.44
87	21.99	4.05	4.44
88	22.06	3.93	4.27
89	22.06	3.93	4.27
90	22.13	3.81	4.o0
91	22.13	3.81	4.10
92	22.20	3.69	3.93
93	22.20	3.69	3.93
94	22.27	3.57	3.76
95	22.27	3.57	3.76
96	22.34	3.45	3.59
97	22.34	3.45	3.59
98	22.41	3.33	3.42
99	22.41	3.33	3.42
100	22.48	3.21	3.25
101	22.48	3.21	3.25

TABLE II-XIV (Cont)

45° REINFORCEMENT PLIES

Ply No.	"D" Dimension (in.)	"E" Dimension (in.)	"F" Dimension (in.)
102	22.55	3.09	3.08
103	22.55	3.09	3.08
104	22.62	2.97	2.91
105	22.62	2.97	2.91
106	22.69	2.85	2.74
107	22.69	2.85	2.74
108	22.76	2.73	2.57
109	22.76	2.73	2.57
110	22.83	2.61	2.40
111	22.83	2.61	2.40
112	22.90	2.49	2.23
113	22.90	2.49	2.23
114	22.97	2.37	2.06
115	22.97	2.37	2.06
116	23.04	2.25	1.89
117	23.04	2.25	1.89
118	23.11	2.13	1.72
119	23.11	2.13	1.72
120	23.18	2.01	1.55
121	23.18	2.01	1.55

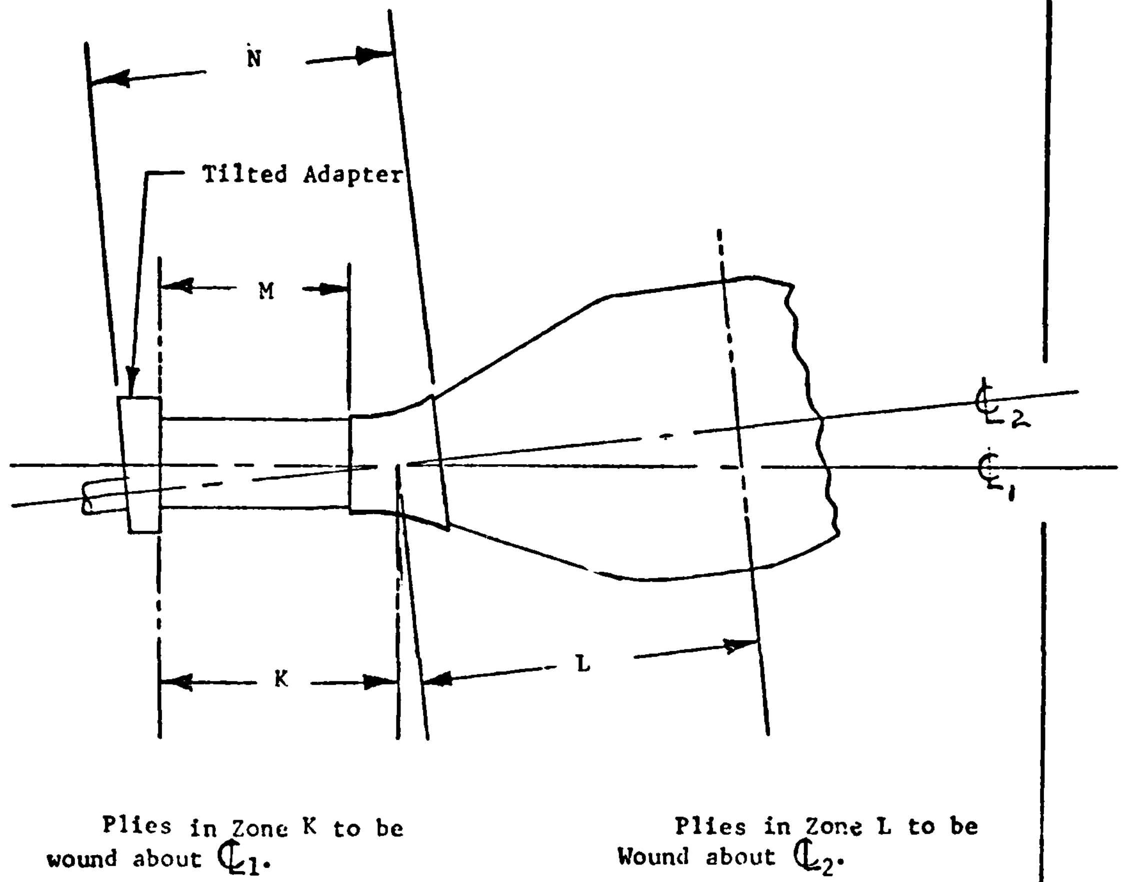


90° plies in Zone H to be wound about $\mathbb{C}_1$.

90° plies in Zone J to be Wound about $\mathbb{C}_2$.

Trunnion Layup Detail
for
90° Plies, Full Coverage

Figure II-41



Trunnion Layup Detail
for
Reinforcement Plies

Figure II-42

TABLE II-XV

FULL COVERAGE 90^{o} PLIES

Ply No.	"G" Dimension (in.)
7	12.10
20	11.66
27a	11.22
36	10.78
49	10.34
60	9.90
67	9.46

18. Compact in accordance with steps 11, 12, 13, and 14.

19. Repeat steps 7 and 8 for layup of Plies No. 8 (0^{o}) and 9a (0^{o}) per Figure II-39 and Table II-XIII.

20. Repeat step 9 for layup of Plies No. 9b ($+45^{o}$) and 9c (-45^{o}) in accordance with Figure II-42 and Table II-XVI).

21. Lay up Plies No. 10 ($+45^{o}$) and 11 (-45^{o}) in accordance with Figure II-40 and Table II-XIV.

22. Repeat steps 4 and 5 for Ply No. 12 (-45^{o}) layup per Figures II-37 and II-38.

23. Compact by repeating steps 11, 12, 13, and 14.

24. Repeat step 6 for Ply No. 13 ($+45^{o}$) per Figures II-37 and II-38.

25. Lay up Ply No. 14a (0^{o}) by repeating steps 7 and 8 in accordance with Figure II-39 and Table II-XIII.

26. Lay up Ply No. 14b (90^{o}) per Figure II-42 and Table II-XVI by repeating step 9.

27. Lay up Ply No. 14c (0^{o}) per Figure II-42 and Table II-XVI by repeating step 9.

28. Lay up Ply No. 15 (0^{o}) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

29. Compact by repeating steps 11, 12, 13, and 14.

30. Lay up Ply No. 16 ($+45^{o}$) per Figures II-37 and II-38 by repeating step 6.

31. Lay up Plies No. 17 (-45^{o}) and 18 ($+45^{o}$) in accordance with Figures II-40 and Table II-XIV.

32. Lay up Ply No. 19a (-45^{o}) per Figures II-37 and II-38 by repeating steps 4 and 5.

33. Lay up Plies No. 16b (-45^{o}) and 19c ($+45^{o}$) in accordance with Figure II-42 and Table II-XVI by repeating step 9.

34. Wind Ply No. 20 (90^{o}) according to Figure II-41 and Table II-XV by repeating step 17.

TABLE II-XVI

LOCAL REINFORCEMENT PLIES

Ply No.	Orientation (Deg)	"M" Dimension (in.)	"N" Dimension (in.)
3b	-45	11.77	13.39
3c	+45	11.77	13.39
6b	0	11.645	13.515
6c	0	11.645	13.515
9b	+45	11.520	13.640
9c	-45	11.520	13.640
14b	90	11.395	13.765
14c	0	11.395	13.765
19b	-45	11.270	13.890
19c	+45	11.270	13.890
22b	0	11.145	14.015
22c	0	11.145	14.015
27b	+45	11.020	14.140
27c	-45	11.020	14.140
30b	90	10.895	14.265
30c	0	10.895	14.265
35b	-45	10.770	14.390
35c	+45	10.770	14.390
38b	0	10.645	14.515
38c	0	10.645	14.515
43b	+45	10.520	14.640
43c	-45	10.520	14.640
48b	90	10.395	14.765
48c	0	10.395	14.765
51b	-45	10.270	14.890
51c	+45	10.270	14.890
56b	0	10.145	15.015
56c	0	10.145	15.015
59b	+45	10.020	15.140
59c	-45	10.020	15.140
62b	90	9.895	15.265
62c	0	9.895	15.265
65b	-45	9.770	15.390
65c	+45	9.770	15.390
68b	0	9.045	15.515
68c	0	9.045	15.515
71b	+45	9.520	15.640
71c	-45	9.520	15.640
73b	0	9.020	16.140
73c	0	9.020	16.140

35. Compact by repeating steps 11, 12, 13, and 14.

36. Lay up Plies No. 21 (0^{o}) and 22a (0^{o}) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.

37. Lay up Plies No. 22b (0^{o}) and 22c (0^{o}) per Figure II-42 and Table II-XVI by repeating step 9.

38. Lay up Ply No. 23 (-45^{o}) per Figures II-37 and II-38 by repeating steps 4 and 5.

39. Compact by repeating steps 11, 12, 13, and 14.

40. Lay up Plies No. 24 ($+45^{o}$) and 25 (-45^{o}) per Figure II-40 and Table II-XIV.

41. Lay up Ply No. 26 ($+45^{o}$) per Figures II-37 and II-38 by repeating step 6.

42. Wind Ply No. 27 a (90^{o}) per Figure II-41 and Table II-XV by repeating step 17.

43. Lay up Plies No. 27b ($+45^{o}$) and 27c (-45^{o}) per Figure II-42 and Table II-XVI by repeating step 9.

44. Lay up Ply No. 28 (0^{o}) by repeating steps 7 and 8 in accordance with Figure II-3a and Table II-XIII.

45. Compact by repeating steps 11, 12, 13, and 14.

46. Lay up Ply No. 29 (0^{o}) by repeating steps 7 and 8 in accordance with Figure II-39 and Table II-XIII.

47. Lay up Ply No. 30a ($+45^{o}$) in accordance with Figure II-39 and II-40 by repeating step 6.

48. Lay up Plies No. 30b (90^{o}) and 30c (0^{o}) per Figure II-42 and Table II-XVI by repeating step 9.

49. Lay up Ply No. 31 (-45^{o}) in accordance with Figures II-39 and II-40 by repeating steps 4 and 5.

50. Lay up Plies No. 32 (-45^{o}) and 33 ($+45^{o}$) per Figure II-40 and Table II-XIV.

51. Compact by repeating steps 11, 12, 13, and 14.

52. Lay up Plies No. 34 (0^o) and 35a (0^o) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

53. Lay up Plies No. 35b (-45^o) and 35c ($+45^o$) per Figure II-42 and Table II-XVI by repeating step 9.

54. Wind Ply No. 36 (90^o) in accordance with Figure II-41 and Table II-XV by repeating step 17.

55. Compact by repeating steps 11, 12, 13, and 14.

56. Lay up Plies No. 37 (-45^o) and 38a ($+45^o$) in accordance with Figures II-37 and II-38 by repeating steps 4, 5, and 6.

57. Lay up Plies No. 38b (0^o) and 38c (0^o) in accordance with Figure II-42 and Table II-XVI by repeating step 9.

58. Lay up Plies No. 39 ($+45^o$) and 40 (-45^o) per Figure II-40 and Table II-XIV.

59. Lay up Ply No. 41 (0^o) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.

60. Compact by repeating steps 11, 12, 13, and 14.

61. Lay up Ply No. 42 (0^o) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

62. Lay up Ply No. 43a in accordance with Figures II-37 and KK-38 by repeating step 6.

63. Lay up Plies No. 43b ($+45^o$) and 43c (-45^o) in accordance with Figure II-42 and Table II-XVI by repeating step 9.

64. Lay up Ply No. 44 (-45^o) in accordance with Figure II-37 and II-38 by repeating steps 4 and 5.

65. Lay up Plies No. 45 (-45^o) and 46 ($+45^o$) in accordance with Figure II-40 and Table II-XIV.

66. Compact by repeating steps 11, 12, 13, and 14.

67. Lay up Plies No. 47 (0^o) and 48a (0^o) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

68. Lay up Plies No. 48b (90^o) and 48c (0^o) in accordance with Figure II-42 and Table II-XVI by repeating step 9.

69. Wind Ply No. 49 (90°) in accordance with Figure II-41 and Table II-XV by repeating step 17.

70. Compact by repeating steps 11, 12, 13, and 14.

71. Lay up Plies No. 50 (-45°) and 51a ($+45^{\circ}$) in accordance with Figures II-37 and II-38, steps 4, 5, and 6.

72. Lay up Plies No. 51b (-45°) and 51c ($+45^{\circ}$) in accordance with Figure II-42 and Table II-XVI by repeating step 9.

73. Lay up Plies No. 52 ($+45^{\circ}$) and 53 (-45°) per Figure II-40 and Table II-XIV.

74. Lay up Ply No. 54 (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.

75. Compact by repeating steps 11, 12, 13, and 14.

76. Lay up Ply No. 55 (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.

77. Lay up Ply No. 56a ($+45^{\circ}$) in accordance with Figures II-37 and II-38 and step 6.

78. Lay up Plies No. 56b (0°) and 56c (0°) per Figure II-42 and Table II-XVI by repeating step 9.

79. Lay up Ply No. 57 (-45°) in accordance with Figures II-37 and II-38.

80. Compact by repeating steps 11, 12, 13, and 14.

81. Lay up Plies No. 58 (0°) and 59a (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

82. Lay up Plies No. 59b ($+45^{\circ}$) and 59c (-45°) in accordance with Figure II-42 and Table II-XVI by repeating step 9.

83. Wind Ply No. 60 (90°) in accordance with Figure II-41 and Table II-XV by repeating step 17.

84. Compact by repeating steps 11, 12, 13, and 14.

85. Lay up Plies No. 61 (-45°) and 62a ($+45^{\circ}$) in accordance with Figures II-37 and II-38, steps 4, 5, and 6.

86. Lay up Plies No. 62b (90°) and 62c (0°) per Figure II-42 and Table II-XVI by repeating step 9.

87. Lay up Ply No. 63 (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

88. Compact by repeating steps 11, 12, 13, and 14.

89. Lay up Ply No. 64 (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

90. Lay up Ply No. 65a (+45°) per Figures II-37 and II-38, step 6.

91. Lay up Plies No. 65b (-45°) and 65c (+45°) in accordance with Figure II-42 and Table II-XVI by repeating step 9.

92. Lay up Ply No. 66 (-45°) per Figures II-37 and II-38, steps 4 and 5.

93. Compact by repeating steps 11, 12, 13, and 14.

94. Wind Ply No. 67 (90°) in accordance with Figure II-41 and Table II-XV by repeating step 17.

95. Lay up Ply No. 68a (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

96. Lay up Plies No. 68b (0°) and 68c (0°) per Figure II-42 and Table II-XVI by repeating step 9.

97. Lay up Ply No. 69 (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.

98. Compact by repeating steps 11, 12, 13, and 14.

99. Lay up Plies No. 70 (-45°) and 71a (+45°) in accordance with Figures II-37 and II-38, steps 4, 5, and 6.

100. Lay up Plies No. 71b (+45°) and 71c (-45°) per Figure II-42 and Table II-XVI by repeating step 9.

101. Lay up Ply No. 72 (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.

102. Compact by repeating steps 11, 12, 13, and 14.

103. Lay up Ply No. 73a (0^{o}) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.

104. Lay up Plies No. 73b (0^{o}) and 73c (0^{o}) per Figure II-42 and Table II-XVI by repeating step 9.

105. Lay up Ply No. 74 ($+45^{o}$) in accordance with Figures II-37 and II-38, step 6.

106. Compact by repeating steps 11, 12, 13, and 14.

107. Lay up Ply No. 75 (-45^{o}) in accordance with Figures II-37 and II-38, steps 4 and 5.

108. Lay up Plies No. 76 (-45^{o}); 77 ($+45^{o}$); 78 ($+45^{o}$), 79 (-45^{o}) per Figure II-40 and Table II-XIV.

109. Compact by placing Machburg cloth over patch area and overwind with glass roving while applying heat from heat gun. Allow to cool to room temperature before removing compaction material.

110. Lay up Plies No. 80 (-45^{o}); 81 ($+45^{o}$); 82 ($+45^{o}$); 83 (-45^{o}); 84 (-45^{o}); 85 ($+45^{o}$); 86 ($+45^{o}$); 87 (-45^{o}); 88 (-45^{o}); 89 ($+45^{o}$); 90 ($+45^{o}$); 91 (-45^{o}) in accordance with Figure II-40 and Table II-XIV.

111. Compact by repeating step 109.

112. Lay up Plies No. 92 (-45^{o}); 93 ($+45^{o}$); 94 ($+45^{o}$); 95 (-45^{o}); 96 (-45^{o}); 97 ($+45^{o}$); 98 ($+45^{o}$); 99 (-45^{o}); 100 (-45^{o}); 101 ($+45^{o}$); 102 ($+45^{o}$); 103 (-45^{o}) in accordance with Figure II-40 and Table II-XIV.

113. Compact by repeating step 109.

114. Lay up Plies No. 104 (-45^{o}); 105 ($+45^{o}$); 106 ($+45^{o}$); 107 (-45^{o}); 108 (-45^{o}); 109 ($+45^{o}$); 110 ($+45^{o}$); 111 (-45^{o}); 112 (-45^{o}); 113 ($+45^{o}$); in accordance with Figure II-40 and Table II-XIV.

115. Compact by repeating step 109.

116. Lay up Plies No. 114 ($+45^{o}$); 115 (-45^{o}); 116 (-45^{o}); 117 ($+45^{o}$); 118 ($+45^{o}$); 119 (-45^{o}); 120 (-45^{o}); 121 ($+45^{o}$); in accordance with Figure II-40 and Table II-XIV.

117. Compact as follows: Apply porous scrim cloth over entire layup and cover with one ply of Machburg cloth; fix thermocouple onto prepreg; install vacuum bag; place in vacuum bag and position in autoclave; apply vacuum and pressure; heat part to $250^{\circ} \pm 15^{\circ}$ F; cool part to room temperature before releasing vacuum and pressure.

118. Repeat step 14.

B. Final Cure

1. Cover entire layup with porous scrim.
2. Apply double-faced tape to sloped areas of layup.
3. Wind compacting material over entire layup.
4. Apply thermocouple and install vacuum line.
5. Install in vacuum bag and check for leaks.
6. Place in autoclave.
7. The cure cycle is as follows:
   a. Hold vacuum throughout cycle.
   b. Apply 100 psi pressure intially.
   c. Raise temperature 3° F/minute to 250° F.
   d. Hold at 250° F for one hour.
   e. Raise temperature at 3° F/minute to 300° F.
   f. Hold at 300° F for 30 minutes.
   g. Raise temperature at 3° F/minute to 350° F.
   h. Hold for 2 hours at 350° F and 100 psi.
   i. Cool down to 150° F while maintaining pressure and vacuum.
   j. Remove from autoclave at 150° F or below.
   k. Remove cure materials and equipment.

C. Machining

1. Machine in accordance with drawing (CJA37B10, Rev D).

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